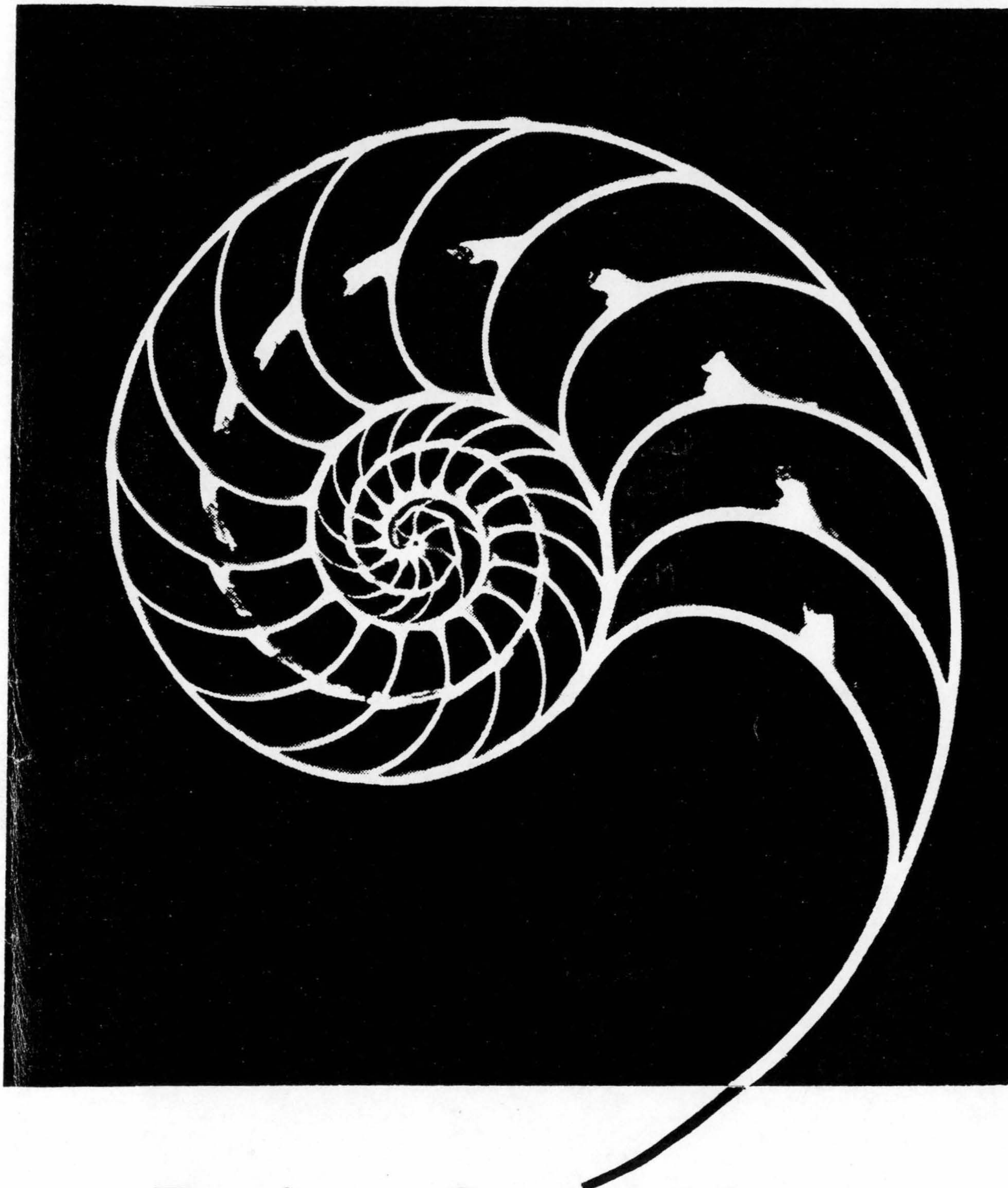
Regenerative Systems



in Design & Architecture.

Gillian van der Schans

REGENERATIVE SYSTEMS
in design & architecture

by
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B.A.Env.Des. B.Arch.(Hons)

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This Thesis contains no material which has been accepted for the award of any other degree or diploma in any other institution and to the best of my knowledge and belief, the Thesis contains no material previously published or written by another person, except where due reference has been made in the text of the Thesis.

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Gillian van der Schans

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Abstract

This thesis presents the architect and designer with a design process that is intended to stimulate the mind and enhance creativity. The regenerative approach encourages the reconsideration, reuse and reapplication of design ideas and design technologies to architecture. It is based upon the notion and well tested belief that design can not occur in a vacuum, void of experience and therefore inspiration. Design requires a source, a spark of inspiration, to ignite the imagination and motivate the soul to creative action. The thesis discusses in detail the potential scope of such stimulative sources, and the numerous techniques and methods that may be employed to uncover the *primary generator*.

The regenerative approach aims to increase creativity by increasing the architect's understanding of associative and creative processes. This includes promoting observation and the active stockpiling of visual data as a key to creative thought. It is suggested that if designers increase their creative input, they may potentially increase their creative output. Many of the finest architects and designers are renowned for creative pilfering and stockpiling of ideas. They may be viewed as the bower birds of society, in constant search of attractive and sparkling ideas to apply to the art of building.

The discussion and analysis of numerous examples and relevant design issues, concludes in a number of design guidelines. These make relevant the regenerative theories to design practice, and may be of use to the architect or designer wishing to improve their ability to come up with 'new' ideas.

1.

Preface

This thesis is derived from a deep interest in creative processes and in how ideas are sourced. I hope the content will stimulate those with a comparable interest and passion for design. Much of the thesis can be read not only as a discussion about architectural design but also as an investigation into the greater umbrella of design. The associative design approach is applicable to many creative pursuits and activities.

In any design-related discussion the author is treading on fragile ground. I realise that in discussing the innately subjective topics of design and creativity I am potentially opening many doors of criticism. The reader may not agree with all the conclusions but hopefully some of them will strike a common chord. At this point I would like to quote Arthur Koestler from his book 'The Act of Creation', and say that like him:

"I have no illusions about the prospects of the theory I am proposing; it will suffer the inevitable fate of being proven wrong in many, or most details, by new advances in knowledge. What I am hoping for is that it will be found to contain a shadowy pattern of truth." 2.

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Introduction

The aim

This thesis aims to demonstrate and discuss the existence of a regenerative pattern in architectural design. The aim is to see whether there is a useful concept of regenerative design. The objective to analyse methods of sourcing, analysing and implementing ideas, and discover some guiding principles behind the ideas and examples discussed. This thesis has enlightened my own design process, and it is hoped that it will do the same for others.

The method

To achieve this aim the intention is to examine regenerative patterns and regenerative precedents in design and architecture. Discussions on the method of sourcing and implementing ideas and numerous related design issues presents a background of evidence. This evidence highlights the value of the regenerative process and its ability to unlock design ideas. From the discourse, key points are extracted to form a set of guidelines and concluding remarks, these are designed to aid in the introduction of the regenerative concept to the design process.

The regenerative activity

"Haroun sighed. 'I don't think I'll ever get the hang of this place. What do fish do, anyway?' Iff replied that the Plentimaw Fishes were what he called 'hunger artists' - 'Because when they are hungry they swallow stories through every mouth, and in their innards miracles occur; a little bit of one story joins on to an idea from another, and hey presto, when they spew the stories out they are not old tales but new ones. Nothing comes from nothing, Theiflet; no story comes from nowhere; new stories are born from old - it is the new combinations of that make them new. So you see, our artistic Plentimaw Fishes really create new stories in their digestive systems" 1. (S.Rushdie)

This thesis considers a design process and an idea-finding activity that is essentially about purposely reexamining design models that have direct ties to the new design programme, and using this analysis to inspire further design thought and creativity. As stated by C. Abel in 'The Role of Metaphor in Changing Architectural concepts'.

"New ideas come into being by virtue of being able to see the new in terms of the old," 2.

The writings emphasise the continuity between ideas, and suggest that a design's development may be viewed as an evolutionary process, or otherwise as a catalytic reaction between existing ideas. Architects may learn a great deal through the study of regenerative pathways and heredity patterns. Once again as C. Abel states in 'The Role of Metaphor in Changing Architectural concepts'.

"There is a continuity between past, present and future inscribed into generations of new ideas which I believe that we have not fully understood." 3.

The thesis acknowledges that very few ideas are totally new and suggest that creation isn't making something out of nothing. It suggests that creation more often than not involves the development or the rearrangement of existing design technologies. As Aristotle so wisely recommended:

"hunt for the next in the series, starting our train of thought from what is now present or from something else, and from something similar or contrary or contiguous to it." 4.

Regenerative processes in design have been employed since the beginning of time. I readily acknowledge that I am not identifying a new concept but simply highlighting a process that already exists, and awaking the architect's mind to a design process that they may have instinctively used.

An essential ingredient and component of the regenerative equation is the *'primary generator'*. The primary generator is the design hint that comes from an existing model. It may be viewed as the initiator of a regenerative design process. This initial design hint may rise to the surface of our imagination in various forms. It may surface in the form of an object or possibly as a less easily defined experience. This thesis presents techniques and methods that may be used to seek the primary generator and then discusses design methods that may be employed to stimulate the creative mind through further association and analysis of the primary generator.

The regenerative process may be perceived as a continuous system of recycling ideas. Once an idea is realised and introduced into the design world it will be scrutinised by many designers and potentially reinterpreted by another creative mind. The regenerative development of ideas has vast potential, as there is always the opportunity to improve a design or the potential to be reinspired by an old idea.

Ideas have the potential to be exchanged and remodelled within the domain of architecture or designers may discover design hints by observing other disciplines. There are numerous ideas awaiting rediscovery, if only the boundaries between the specialist disciplines are resolutely crossed.

In the regenerative process the architect employs the discovered primary generator as a model and a guide for their own design problem. The new problem is then assembled in a way that is reflective of the generative model. In this process of associative problem solving by regenerative means the architect firstly identifies and establishes a clear understanding of the architectural problem. Secondly, recalls or researches one or more past problems that bear a similarity to the new problem, establishing the grounds of association. Thirdly, proceeds by testing the potential application of the comparative solution to the new problem and design situation, and finally further generalises recurring patterns into a reusable plan or approach that may be applied to a range of other design problems.

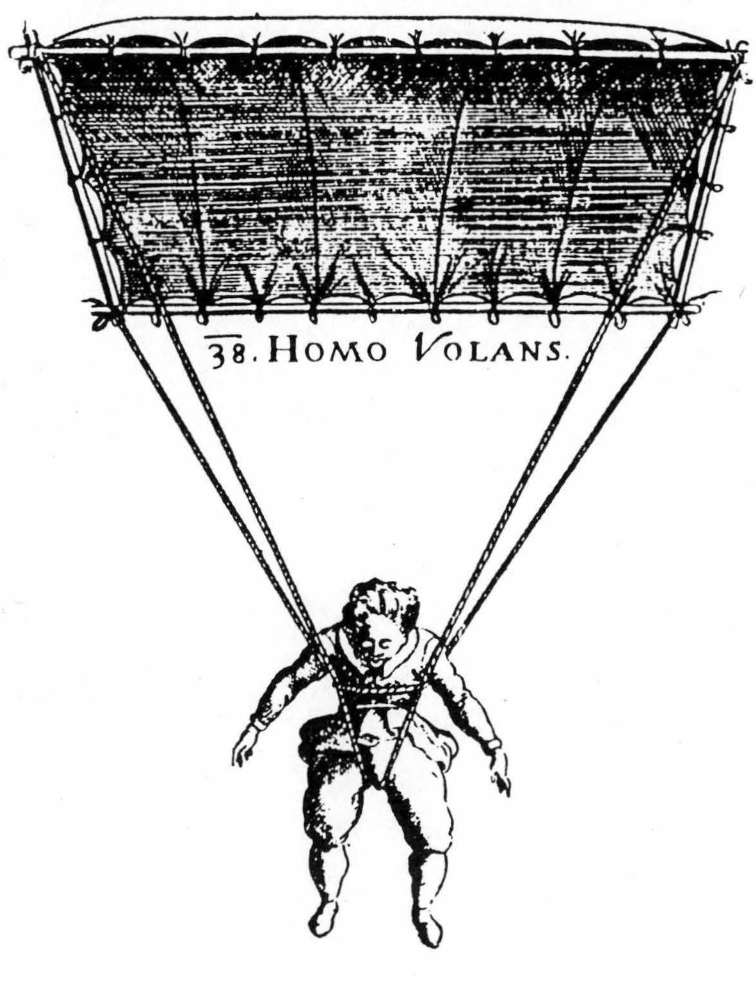
The thesis presents not a formulaic approach to design, that has the grave potential of abstracting the design process, but a holistic outlook that is designed to increase the architect's confidence and skill in revealing ideas that are applicable to building design.

Design by model precedent is a safe and sound process. The regenerative approach bases its advancement upon what has been learnt through past experience. If a result has succeeded once, logic suggests that it may work again. The designer may be highly selective taking only the good ideas and discarding the less successful material. Under such conditions the architect may move forward in design with greater certainty. In a regenerative process the designer may use the primary generator as a predictive model. It may be used to forecast the design outcome and may provide the designer with a certain amount of pretested knowledge.

The thesis examines the issues and a number of approaches that may aid in the realisation of a regenerative idea into a built form. These writings examine the gauges that control and limit architecture as ultimately the difference between a good idea and a successful building is the application of the idea to a built reality.

The thesis concludes by presenting a summary of design principles that are intended to aid in the sourcing of regenerative ideas, the development of the regenerative idea and in the application of the regenerative idea to architecture. The guidelines are presented with the aspiration to improve the designer's judgment and enhance creativity.

A regenerative view enables the designer see new design potential in many past and present design technologies. The thesis aims to stimulate the creative minds of architects by providing them with a creative approach and structure that will aid in that elusive search for ideas.



Setting the context

Regenerative patterns

The regenerative process is a basic component of our everyday life and an essential ingredient of our epistemology. The process of regeneration has been considered from early times. As Plato stated;

"All phenomena are in a never ending process of transformation from one thing to another." 1.

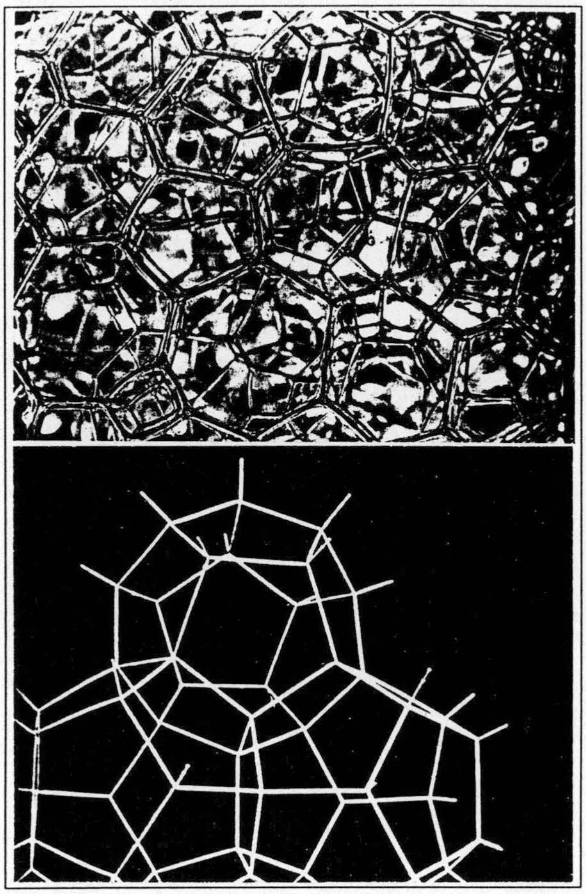
Regenerative processes can be observed in many of the countless number of systems that constitute our Universe. They may be found on a microscopic to the universal scale. For example, on a universal scale we may view the periodical reappearance of comets travelling though outer space. On an intermediate level one may view the life cycle of a chrysalis, observing the creature develop from an egg into a caterpillar, from a caterpillar into a butterfly, that will in time complete the cycle by producing an egg before it dies. On a microscopic scale one may observe the formation of ice crystals, on a waters surface, watching as the water warms the same compound transform or melt back into a liquid state. With further heat we may observe the compound vaporise. In each of the three cases described the phases observed represent a different regenerative state of the same entity.

The recurrent processes of nature, such as those discussed above, may be compared to the recurrent and periodical reappearance of design ideas. In design the idea often travels a cyclic path, reemerging in a manner not unlike the reappearance of a comet. The 'comet' or the design concept, as it may be, will appear in relation to the earth and mankind on a periodical basis. On each reappearance the idea, like the comet, will be viewed differently as the tools, knowledge, ontology and experience available to examine the comet or idea will be different than that available at its previous time of appearance. Another comparative analogy that may be discussed is the comets form, its size, its shape and density may alter within the time that the celestial body is beyond our view. In an equivalent manner so may the idea alter between the periods that it is beyond our personal view.

One may suggest that this thesis, like any other is in itself an example of the regenerative arrangement of knowledge. The information it contains is not *new* but it has the potential to add to the sum of knowledge in a recursive manner. New knowledge may be sought via a process that compares existing knowledge, using the resulting associations and interconnections to establish further ideas and further comparative possibilities.

The regenerative tool

As stated by the Macquarie dictionary to regenerate is:
"To recreate, reconstitute or make over, especially in a better form or condition. To generate or to produce a new, bring into existence again." 1.



This definition states quite clearly what a regenerative approach involves. The designer 'recreates' by examining the created and improving upon it. This may be achieved by either the stage by stage development of an existing idea, in its existing design context, or by the transfer of the idea or information discovered into a totally new design location, where it may be used to generate a new design. An important aspect of the definition is that as it suggests to regenerate is to recreate 'in a better form or condition'. Likewise in 'regenerative design' the idea is not only brought into existence again but it is improved upon.

Structural experiments by Frei Otto 2.

Most problems that confront the designer require a certain amount of creative reflection to solve. Many designers may already employ a regenerative approach to uncover ideas without being consciously aware of their design actions. Another possibility is the designer may avoid identifying the source of their ideas even though they may have quite conscious and explicit origins. In design there is very little encouragement to acknowledge the source of an idea as often more prestige is associated with invention than with the development of an existing idea.

The regenerative approach may be purposely employed, like a tradesman's tool, to seek and construct creative design solutions. This design tool is not limited to architecture, the regenerative approach to design and creative thinking may be applied to furniture design, yacht design, or any other form of design such as painting or sculpture. It may be applied to curing a disease, propelling a car or even programming a computer. All professions can benefit from this approach, under the appropriate circumstances an idea may be exchanged, remodelled and reapplied 'ad infinitum'. For example a new material may be applied in a regenerative sense to medicine, (possibly in the construction of an artificial joint) to automobile design, or architecture. The 'primary generator', or as in this case a technological generator, in the form of a new material, may follow a convoluted and complex series of design exchanges. The number of times a regenerative idea can be applied is unlimited as the idea will always retain the potential to inspire a future design.

Association

"The conscious and unconscious processes underlying creativity are essentially combinatorial activities - the bringing together of previously separated areas of knowledge and experience. The scientist's purpose is to achieve *synthesis* ; the artist aims at *juxtaposition* of the familiar and the eternal; the humorist's game is to contrive a *collision*." 1.

As Koestler suggests in the above quote, creativity involves 'combinatorial' activities that are both 'conscious' and 'unconscious'. There are those associative design decisions that we choose with reason and intent and there may be those associative processes that occur beyond the realm of our conscious action, the architect or the designer may experience both. In this discussion, directed towards improving design skill, we are most interested in the tangible side of design thinking, in the side we can control and possibly train and improve. These are the conscious processes of association.

Association may be viewed as a mental process that gears the imagination to our memory and allows one design thought to lead to another. A regenerative approach encourages associative games as many design problems may be solved in this way. The designer may choose, when faced with a new problem, to summon one combination of ideas after another, forming mental combinations, and testing their validity, until an appropriate and reusable idea is found.

The power of association, as a creative device, has been recognised by many people for many years. Aristotle was one of the first to recognise the importance of association and to stress a link between it and creativity. In his writings he discussed three methods of association; Those being *similarity*, *contiguity* and *contrast*. *Similarity* as he suggested was based upon metaphor and simile, with the resulting associations formed upon the grounds of resemblance. Association by *contiguity* , as Aristotle believed was where a part suggested a whole or a whole suggested a part. By Aristotle's uniting process of *contrast* ideas are associated by the differences that predominates between them.

If these categories of association are applied to architecture we may construct the following examples;

- By *similarity* we may say that a nuns hat is like the Chapel at Ronchamp by the architect le Corbusier, or an eggs shell is like the roof of the Sydney Opera House, by Juorn Utzon.
- By *contiguity* a small tile may remind us of Parc Guell by Antonio Gaudi, or a piece of broken glass suggest a stained glass window.
- By *contrast* a heavy wall may be associated with a light Japanese screen, or a spire with a pneumatic bubble.

Design associations may not only be established through visual connection, they may in fact be recognised by any of our senses. For example, through hearing the sound of a creaking board may remind the designer of a timber yacht. Through touch, the texture of concrete may remind the designer of velvet, (as by contrast). Through smell, a certain spice may remind us of another culture. Through taste, a certain drink may remind the designer of particular place where they may have last tasted it, (as by contiguity). From such converging sensory associations the architect may withdraw regenerative inspiration for design. Our senses, excluding sight, are not often employed to their potential capacity in architecture as effective design stimulators.

Association has throughout history led to a profound number of design discoveries. For example, Johann Gutenberg discovered and developed the printing press through a complex process of sensory association. Gutenberg set himself a goal to seek a quicker method of book production rather than laboriously carving letters and words on a single block of wood and then transferring them to paper by inking the engraving and rubbing paper on to it. At first he toyed with the idea of casting letters, in an associative sense, like seals which would permit them to be used over and over again. The problem with this idea was that they would not leave a clear enough impression on the paper if they were merely rubbed against it. One day when observing a wine press at work the two trains of associative thought, one dealing with the wine press and the other with the seal converged. In this instance Gutenberg rearranged and synthesised what was known, in order to find what was not known. By a process of association, Gutenberg discovered a method of printing that was infinitely faster than any of the traditional methods.

In design as in every facet of our complex world there are aspects that we can not as yet explain. It is inconceivable that mankind could devise a creative formula that could replace the cognitive phenomena described above. Gutenburg's regenerative design solution is based upon the undefinable behaviour and design capacity of our five human senses. Such a process can not be pinned down or wholly translated into rigid scientific terms. The alluring field of Artificial intelligence is based upon the somewhat optimistic belief that we can extract the essence of creativity and evolve it into a formula or a programme that will have the ability to imitate human creative behaviour. Even though the results of this scientific pursuit have been to a degree unyielding, the associated research has been very useful in clarifying ideas on aspects of human thought. For years, artificial intelligence has been accused of promising too much and delivering too little, yet a recent offshoot entitled case base reasoning or C.B.R is beginning to prove itself in practical problem solving.

"One advantage of C.B.R is its conceptual simplicity. Just as humans tend to solve problems by drawing on their experience, C.B.R. works by adapting solutions that were used to solve old problems. The user presents the new problem to a computer that contains a library of hundreds of thousands of past cases. The computer retrieves the most similar case and, if necessary, adapts it to suit current circumstances......In some circumstances, it can be more useful than neural network systems, which are computing devices that are capable of picking out patterns from large data bases. Whereas Neural network cannot explain its findings, a C.B.R. system can supply supporting reasoning.....'C.B.R is perhaps the first fruits of spring following the artificial-intelligence winter.'" 2.

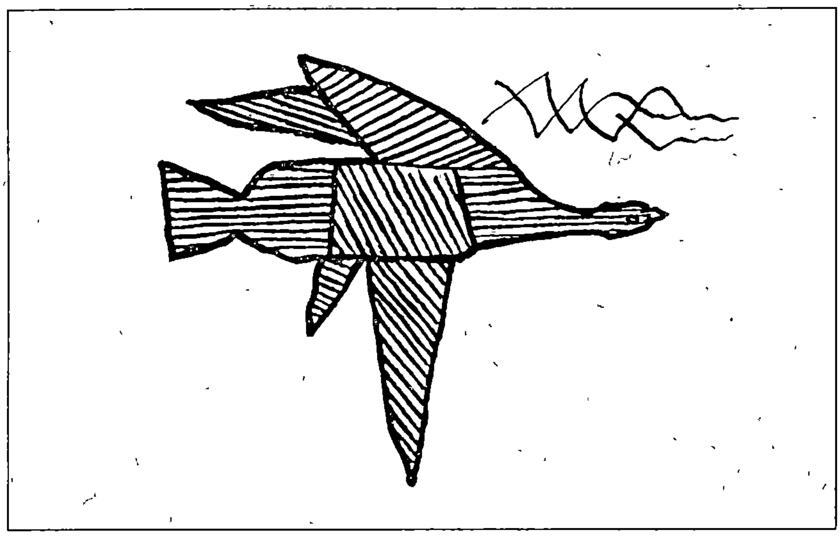
C.B.R works as a creative support system. This system has distinctive parallels with the regenerative design process being presented by the thesis. It does not not attempt to present a formula to replace creativity but present examples along a regenerative theme that may enhance the operators *existing* creative capacity. It emphasises the value of associative and experience based knowledge in solving problems, which is vastly different from some other forms of artificial intelligence, such as rule based systems that purport to diagnose a problem. C.B.R. does not appear to exaggerate its potential. It presents the associative possibilities, enhancing our experience based knowledge, and does not attempt to replace human judgment.

Association, if transformed into a traditional law based formula, would ultimately suffer a degree of impoverishment and distortion. A programmed response following a set of interpreted laws will always be a lesser one than a response unrestrained by such laws. Ultimately the consequences of creativity can not be precisely measured, they can not be predicted or devoutly controlled. Human freedom, uniqueness and an innate desire to manipulate, inevitably limits what a scientific analysis of creativity can accomplish. If we wish to establish a valid theory of design, a flexible guide is possibly all we should hope to achieve.

The quotes below by Alex Osborne and George Braque are in definite support of the belief that we can not strictly mould our creative behaviour into a formulated or scientific approach.

"I Submit, that creativity will never be a science - in fact much of it will always remain a mystery..." 3. (A.Osborne)

"There are certain mysteries, certain secrets in my own work which even I don't understand, nor do I try to do so..... The more one probes the more one deepens the mystery: It's always out of reach. Mysteries have to be respected if they are to retain their power. Art disturbs; science reassures." 4. (George Braque)



George Braque. 5.

In design and architecture, association needs to be recognised as an exceptionally useful creative device in idea production and one that has proven itself to be very useful in the search for a primary design generator or creative stimulant.

Idea production

1. It is very difficult to pin point exactly how ideas are born. Under a regenerative light, the production of ideas depends upon the contents of one's mind and upon how these ingredients are mixed together to derive a design solution. This simplistic description tends to suggest an imitatable approach, but the variables in the process are infinite as every person's mind is filled with an amorphous body of information that is constantly being added to, reassessed and distorted by the individual's imagination. The creative ingredients in one mind are simply unlike the creative ingredients in any other.

As S.J. Parnes and H.F. Harding suggest in the following paragraph the process of mixing ideas can be compared to a view through a kaleidoscope.

"When you look into the kaleidoscope, you see a pattern. If you manipulate the drum of the kaleidoscope, you begin to get countless patterns. If you then add a new piece of crystal to the kaleidoscope, and hold the drum still, you get a slightly different pattern. Now if you manipulate the drum, with the new stone included, you have a multitude of new possible patterns.

The mind works in a similar way. If you 'look into the brain,' you find millions of bits of knowledge and experience stored there-like the information stored in the memory drum of a computer. If you manipulate, 'turn on the computer,' you get countless patterns-ideas produced by combination and re-combination of the existing elements. If you add a new fact or experience, as in adding a new piece of crystal to the kaleidoscope, you add one new pattern. However as soon as you begin to *manipulate*, combining and rearranging the new fact with the old, you get an even greater number of new possible patterns of ideas." 2.

This description of creative thought presents an enlightening proposal as to how ideas may be produced. It is of particular interest as the passage does not attempt to simplify the task but it reveals to us how complex and layered the process may be.

Preparation for the task of regenerative design.

Designers may not be able to devoutly control or fully understand their creative instincts but they may, by being aware of some of their own creative patterns, be able to further increase their design productivity and creative insight. Many creative people understand the conditions under which their best design ideas emerge. They are attentive to both the physical environment and to the nature of their own internal state of mind in which they are most creative. The possible range of environmental conditions conducive to creativity is enormous. For example; noise may stimulate one mind, yet total silence another. Ideas for some may tend to appear in the morning and for others they may tend to appear at night. Ideas may emerge in a relaxed or an inactive state of mind, or their appearance may involve perspiration and physical action.

All of these environmental conditions are introspective. A designer may find that they require conditions in opposition when compared to one another, or they may find that their own personal creative requirements alter from time to time, swinging from one extreme to another.

Creative ideas may not eventuate unless we know how to identify them. A designer's mind needs to be prepared and receptive to receive ideas, and will need to be able to recognise and understand the value of them when they present themselves. In creative problem solving far more than chance is involved. The designer may, as Alex Osborne suggests in the following passage, be able to partially direct and guide their flow of thoughts to increase their creative capacity.

"although association normally runs through our mental hose hither and yon, and willy nilly- if we keep the nozzle trained on the creative task at hand, we can make the flow of association spout more seeds for us." 1.

As the passage suggests, design requires a concentration of energy upon a given task. Possibly applied energy can increase creativity in the same way as the gardener's labour can sprout more seeds. To continue this analogy, architects may increase their crop of ideas and their creative productivity, by becoming more aware of the creative tools available to nurture the design process.

New concepts and ideas

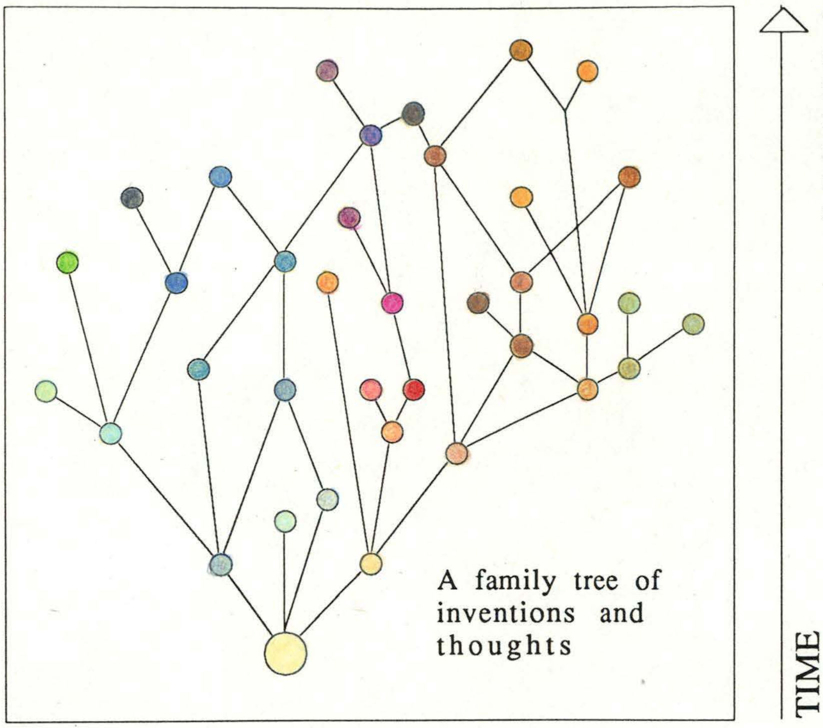
"Most ideas are combinations of, or improvements upon, other ideas. That is why synthesis is so often claimed to be the most fruitful means of creative procedure." 1.

The regenerative approach is based upon the belief that many of the so called 'new' ideas do in fact directly spring from other ideas. These 'new' ideas have been formed by what may be viewed as either an evolutionary development, or a catalytic reaction, producing a change in the idea's character. The view that all ideas stem from others is recognised by numerous writers and design philosopher. It is this conformity of opinion that has provided the trigger for the examination of a regenerative approach to design. Schon clearly supports this regenerative view in the following quote.

"New concepts do not spring from nothing or from mysterious external sources. They come from old ones... New concepts emerge out of the interaction of old concepts and new situations where the old concepts are not simply reapplied unchanged to a new instance but is that *in terms* of which the new instance is seen. This is what we have described as the displacement of concepts-a process in which old concepts, in order to function as projective models for new situations, come themselves to be seen in new ways." 2.

What can be considered 'new' in design is difficult to define. There are numerous ideas that are earmarked as 'new' that may be traced to a yielding source. In this case we may question whether it is truly a 'new' idea,. A source suggests that the ideas are 'regenerative' rather than 'new'. Referring to this issue King Solomon is reported to have said, "Nothing under the sun is new". 3.

The development of ideas may be viewed as a family tree of inventions and thoughts with any number of paths to follow or inter-connections to be made. The following diagram conceptually represents this idea. The slight modifications and developments over time result in the existing idea disassociating itself from the original design model.



A family tree of inventions and thoughts

The ideas on the outskirts of the family tree of ideas may show little resemblance to their original source.

The colours on the diagram most effectively represent this idea. All the colour pods contain a quantity of the original shade of yellow yet they have been altered by the addition of other tones. The result is colour distortion to the point where they show little resemblance to the original source.

Arthur Koestler plainly demonstrates and compares the processes of design succession and evolution in the following passage.

"Motor-car manufacturers take it for granted that it would make no sense to design a new model from scratch; they make use of already existing assemblies - engines, batteries, steering systems, etc. - each of which has been developed from a long previous experience, and then proceed by small modifications of some of these. Evolution follows a similar strategy. Compare the front wheels of the latest model with those of an old vintage car or a horse and cart - they are based on the same principles. Compare the anatomy of the fore-limbs of reptiles, birds, whales and man - they show the same structural design of bones, muscles, nerves and blood vessels and are accordingly called 'homologous' organs. The functions of legs, wings, flippers and arms are so different that one would expect them to have quite different designs. Yet they are merely modifications, strategic adaptions of an already existing structure." 4.

Appreciating such an evolutionary pattern may benefit the architect. Numerous building technologies, like car technologies, have been based upon past experience and well tested design experimentation. Developing an existing palette of ideas in slight increments may be, as nature has shown us, a most effective method of design generation.

Innovation and Invention

Innovate "to bring in something new; make changes in anything established. to bring in (something new) for the first time." 1.

Invent "to originate as a product of ones own contrivance, to produce or create with the imagination....... to devise something new, as by ingenuity" 2.

'Innovation' and 'invention' are creative terms that require discussion in a regenerative context. Both terms reemphasise the existence of a regenerative pattern in design and bring forward further debate.

The term 'innovation' recognises, by its own definition, that ideas may be derived from existing ideas. It partly refers to changes 'in anything established'. The innovation, like the regenerative development is an advancement upon another idea, a 'change' for the better. The Macquarie definition acknowledges that ideas may have an origin from where they begin, suggesting a design continuity between design innovations. Aspects of exchange and conveyance are also identified in this definition of innovation, 'to bring in' an idea is an act of transfer. Transferring ideas is undoubtedly a part of the regenerative activity. In the associative process we collate and compare ideas, adding them to one another. Technical knowledge is imported and transferred from one discipline to another.

In contrast, invention suggests not a growth and developmental process, but a spontaneous and mysterious form of internal reaction. A mixing of ideas beyond the conscious realm. We may view an invention as a liquid idea or a viscous substance welling up into our conscious state of mind as a design idea. This substance is created in the gestation pot of our subconscious and contains a mix of of our experiences as gathered through our five senses. The instinctive response is an appreciated and highly respected aspect of design. As expressed by Alex Osborne much of the creative process, 'will always remain a mystery' 3. Or as Braque quoted. 'Mysteries have to be respected if they are to retain their power' 4. The regenerative process may be presented as a process to consciously increase creativity, but the author does not suggest that the unconscious can be ignored or that creativity will ever be *devoutly controlled.*

The definition of invention may present a view that is dissimilar to innovation but it is equally as relevant. It suggests that ideas are drawn from within, from an internal mixing pot. In contrast, innovation emphasises a clear origin at a conscious level, identifying the innovation to be an alteration upon what is existing.

Parallel thought

By yet another view, ideas may be seen to have their time, and simply await identification or discovery by a perceptive recipient. The idea may be described as a lighting bolt, with the potential to strike an earth bound receptor. If this analogy rings true designers need to present themselves as active receptors, establishing the receptive network and leaving their creative terminal open whilst awaiting a reaction.

Ideas, like lighting bolts, may strike more than one mind at the same time. For example when Alexander Graham Bell was working on the telephone, another man, Gray, was also trying to perfect a similar device. Neither man knew about the other, but both saw the need for their creations. Gray and Bell made their breakthrough at the same time but Bell achieved the recognition for the invention, as he beat Gray to the patent office by only two hours. This example suggests that with similar motivation and stimulation, ideas can just as easily be discovered by someone else. If ideas were entirely derivative of personal and internal inspiration, there would be no such cases of parallel invention.

There are many further historical cases of parallel thought that have resulted in comparable solutions. For example we know that numerous societies developed the wheel in isolation. We can claim this because the wheel was developed before the communication channels around the world were open to spread the knowledge of its discovery. The materials used to construct the 'first' wheels vary but the basic concept is the same. The wheel is a circular frame or solid disk arranged to turn on an axis, and is designed for transportation. In this brief case study we find that the equivalent need, that of transportation, was fulfilled by a similar device. The invention of the wheel required the observation of a basic law of nature and the interpretation and application of this observation to design. Potential design models exist all over our planet, as do receptive minds with the power of observation and the ability to creatively apply such principles.

A third, and architectural example of parallel thought, is the invention of the masonry vault. This structural system was developed independently in Mesapotamia as well as in the oriental countries. The vault was a technological improvement of profound proportions, upon a basic post and beam structure. With the structural realisation of the vault architects could span far greater volumes, using the same traditional materials, (referring to stone). Stone has a high compressional strength but is very weak when exposed to tensional forces. A structural vault is a logical solution and a fitting conclusion to the problem of spanning a greater volume with a compression material. It seems in hindsight an obvious mistake to expose a material with a low tensile strength to tension in the form of a beam. A vaulted structure, in contrast, uses stone only in compression, exploiting its natural properties and achieving far greater things. It does not seem hard to believe that the vault may have been discovered and pursued by designers in isolation.

As the previous examples suggest, the discovery of an idea is promoted by numerous contextual factors. Similar stimulants or needs result at times in similar regenerative discoveries. The result may be viewed as a discovery or a creative interpretation of something already in existence. In this case the inventor is accredited for their receptive abilities rather than their formulative ones. The ideas nurtured and formulated by the needs and the desires of our time are, when ripe, plucked like a Newtonian apple from the tree of inspiration.

Experience.

"...all our intuition (subconscious response) is previously learned behaviour (or habit) which works for times for us and at other times against us. From the beginning of life we learn and we commit that learning to our memory. Afterwards we tend to behave in ways that reflect our learning." 1. (D.Koberg & J.Bagnall)

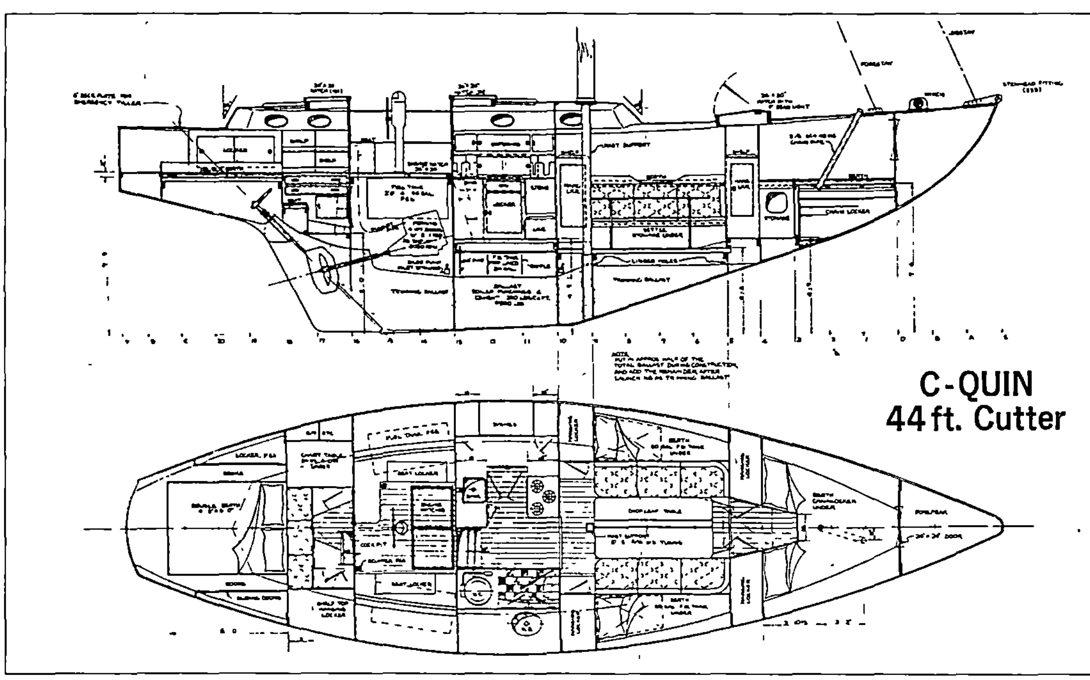
It is commonly accepted that the designer can not work in sensory isolation, or without a reservoir of knowledge and design skill gained from previous experience. We are unable to test such a theory by scientific means as there are really no circumstances under which we can create a void of experience. The brain is a formidable storage bank, filled with experience from a point way back to the beginnings of life in our mother's womb. The human body perceives through a collage of sensory tools. These tools are constantly on the alert to receive information and store it in our memory. Evidently it is experience that shapes a person, a person with a fertile imagination and a memory resource from which to design, create, and generate ideas. As Sir Joshua Reynolds states;

"Invention is little more than new combinations of those images which have been previously gathered and deposited in our memory. Nothing can be made from nothing; those who have laid up no material can produce no combinations" 2.

The development of architecture is heavily reliant upon the accumulation of experience. Building techniques have been improved upon by reflection upon previous attempts. The architectural idea travels through a process of creation, reflection, development and then once again creation. Each stage in this process may involve small improvements in the design or sometimes quite major leaps in design thought. Design is a reflective process, the designer contemplates the site, the climate and the purpose of the building, in addition the designer reflects upon past experiences that have involved these concerns. Christian Norberg-Schulz further announces experience as the design generator in the following quote.

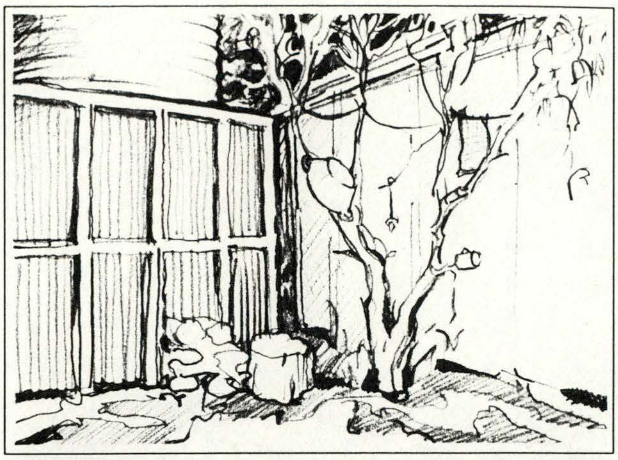
"The architect does not work in a vacuum. His products are solutions to problems coming from the environment, and the solutions have a retroactive effect.....The architect works in 'Situations' which explicitly or implicitly pose particular questions." 3.

The experience of our environment, what ever its form may be directly transformed into an architectural concept. Consider the following images and notes.



For example;

- an experience of small spaces possibly as experienced by living on a yacht or in a caravan may inspire architectural design. 4.

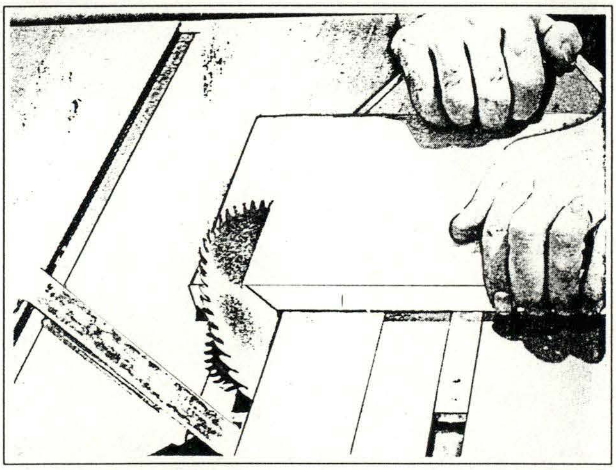


- a resourceful lifestyle experience, possibly as experienced by living in a shack.

Wash up area. 5.

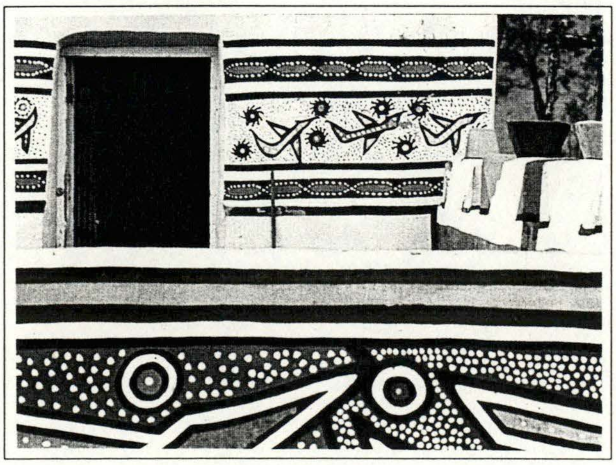
- a lifestyle experience such as the social experience of a fire as the centre of activity, may inspire architectural design.

Preparing dinner. 6.



- the experience of the use of a tool that may allow us to create something in a different way.

Cutting a precise mitre with a circular saw. 7.

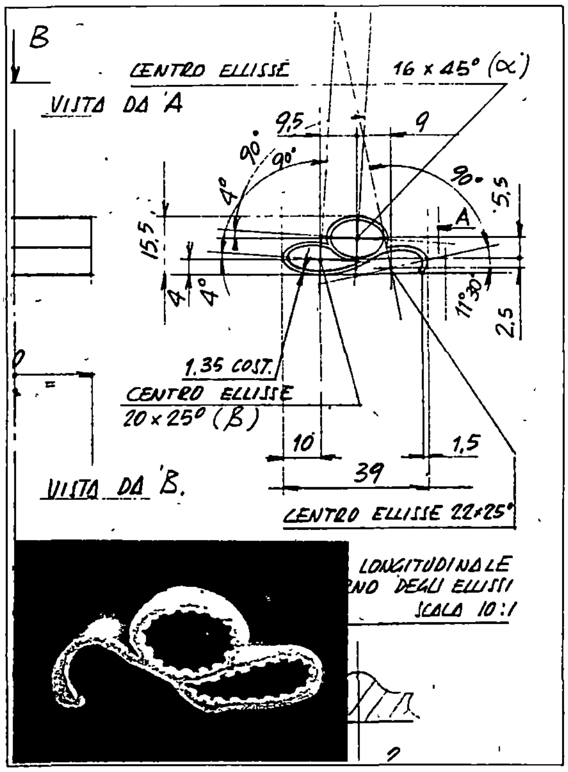


- experiencing the contrasts between different cultures may inspire the designer to explore similar ideas.

An example of Southern Ndebele art and architecture. 8.

The creative spirit

"The history of civilisation is essentially the record of man's creative ability. Imagination is the cornerstone of Human endeavour; it is, without a doubt, responsible for man's survival as an animal; and it has caused him, as a human being, to conquer the world." 1.



The importance of creativity can not be overestimated. Creativity is one of the fundamental differences that exists between man and animal and as A. F. Osborne suggests in the leading passage it may be considered to be the cause of our technological dominance.
The creative mind influences whatever we may do. Our most basic needs have been heavily distorted by our desire for creative expression. For example the basic task of preparing food for consumption, or the task of providing shelter in the form of clothing or built refuge has moved far beyond utilitarian form. The intense desire to manipulate, can be observed in any human context. From the diners seat to a suburban plot.

Even pasta is designed by someone 2.

We are all innately creative and most decisions made will be creative ones. Whether we consider the results successful or unsuccessful our responses will have the ability to inspire another design response. Our creative spirit tends to be instilled into the object as the 'ghost is installed into the machine' 3. The recognition of the creative ghost, in the original object of design, has the ability to excite and reinspire the creative mind. These theories tend to suggest that a design generator for a regenerative response may be discovered in almost any artifact made.

A developmental path

A regenerative concept often develops and matures via a path that involves the interaction of a range of different people with different affiliations and mind sets. Each participant in this process can potentially contribute something unique to the development of the notion. The groupings used in the following diagram to describe the growth of the idea are not rigid categories. Not all creative thinkers will fall distinctly into just one group as the boundaries between them typically merge. The groupings may be viewed as different approaches towards the growth of the concept. These mind sets are formed by ourselves and by our immediate environment. We are all partially instrumental in deciding what we perceive as we select what is significant to us. For example each of these categories may sample the same experience yet they will perceive it quite differently, contributing their own meaning and their own interests to the perception of it. Many designers have the ability to consciously manipulate this mind set and in doing so have contributed to more than one of the groupings identified. In rare instances we find people who have contributed to all three categories.

Theoreticians
Scientists
Philosophers
(the classifiers &
commentators on ideas)

Technologists
(the application
of ideas)

idea

Artists
(the subjective and
emotive application of ideas)

Architects
(the interpretation
& reapplication)

This diagram identifies four groups that may contribute to the growth of an idea.

Theoreticians, Scientists and Philosophers

The theoreticians, the scientists and the philosophers are the analysts and the observers. These people tend to classify, interpret and, commentate on ideas. They are interested in the discovery of new aspects or views about the world we live in. The philosopher may be interested in the truths or in the principles underlying knowledge. The theoreticians may be interested in mental conception, in the hypothetical or in the speculative. The scientist may be interested in the systematic study of a subject, in reproducible observations, deductions, inferences and measurements. All these people tend to commentate on ideas that are either discovered by themselves or in some cases others. The category includes the dreamers, the explorers and the collectors. At this point the idea may be a calculation, an analytical drawing, or a mental concept. The information collectors infrequently consider beyond their discovery. For example, a botanist may discover and record a new type of structure observed in a plant. This information may then be observed, interpreted and applied to design by a technologists or an architect.

The technologists

The technologists are the 'doers'. They are creatively challenged by the task of applying ideas and they are most interested in the idea's potential application to the practical arts. The technologist tends to approach the development of an idea in a most logical and practical way. At this stage the idea may be converted into a test model or prototype, or it may even be released as a product on to the general market. The technologist often see possibilities in and revives those ideas initiated by the theoreticians, philosophers, scientists or architects.

The artists

A broad group who place the value of the subconscious before the conscious, the irrational before the rational and what are non-utilitarian interests before utilitarian ones. Their interests lie in the area of sense perception and manipulation. The artist deals with the abstract science of feeling and adds what can be viewed as an emotive and cultural injection into the growth of the idea.

The architects

The architect, when compared to the technologist, often takes a less rational approach, and may also be viewed as an emotive contributor to the development of an idea. The art in architecture is distinct from the science in technology. This interest influences the architects mind set and affects their response. It is important to note that we are dealing with unstable terms that have and are still undergoing constant redefinition. The distinctions between art, craft, industry, architecture, science and technology have been formed, altered, redefined, influenced, confused, and modified by their historical usage. In its present cultural condition we may say that the artist is distinct from the scientist, as different and contrasting methods and purposes distinguish their behaviour. Less clear is the location of the architect falling somewhere between them. Like the technologist the architect is concerned with the practical application of ideas, like the artist they are concerned with aesthetics and the pursuit of sensory satisfaction. The most obvious difference is that the architect is specifically concerned with these ideas as applied to building. The architect may initiate ideas, but most frequently they apply those ideas developed by others. For example the architect may apply materials designed by the technologists, structures discovered by the scientists, theories developed by analysts or aesthetic principles exposed by artists. The architect is not unlike the bower bird, who unashamedly seeks and collects shiny and attractive objects. The architect tends to collect and apply the fruits of others to the art of building.

Design analysis

Design process

There is a bulk of material written in the area of design studies, and numerous conflicting theories on the creative process. Amongst these there are those discussions that place the analysis of design into a strictly methodical procedure, and there are those discussions that avoid method all together and present the design process as a non-rational event. The 60's and 70's was a period in history renown for presenting the design process in a clear cut and scientific manner. Many of the references from this period are filled with numerical figures and formulas that claim to analyse and describe the design process. Preceding and following this period of thinking we discover an approach that avoids all attempts to logically categorise creative behaviour. The discussions preserve and present the creative act as a mystery. For example the surrealist designers of the 30's and 40's avoided all control of the design process, purposely generating situations beyond the consciousness in which they could design. A regenerative approach to design lies somewhere between such extremes. It suggests that design may be a *partially* controlled activity and that design processes can be enhanced by a higher level of creative awareness. The regenerative approach acknowledges both the unconscious and the conscious aspects of design. The theories are supported with evidence, logic and reason, yet they avoid a fixed or dictatorial stance. It is essential to acknowledge that in design there is always that varying condition to break a set rule.

Fundamental to the success of the creative product is the design approach. When employing a design procedure it is critical to approach it imaginatively. It may be useful to follow design advice but counter-productive to restrain the vision by its limitative boundary. Obviously creativity can not be presented in the form of an instruction booklet, like that written for assembling chair or completing a tapestry. It is possible to present instructions for creativity in the form of guiding principles but it is inadvisable to take them too literally or to follow them too precisely.

Personal convictions should not be ignored.

Architectural design is often presented as a packaged procedure. In the work place the architect tends to group creative activities into activity parcels such as; schematic design, design development, model making, constructional drawing and administration. Each activity is charged for under a separate account and valued rating. This procedure tends to influence the design process, as creative energies are partitioned, weighted and ordered to a similar format. This may be the harsh reality predominant in the commercial application of creativity, but it is not the only way to view the creative act. Drawing, modelling, constructing and thinking may be presented as a continuous and interactive cycle. The design solution may be the result of jumping from one design activity to another. For example the architect may begin with a model, then resolve a detail, and then possibly manipulate the building's internal layout. The architect may limit creativity by strictly dividing the design processes into design events that are confined to an order of occurrence. Often the architect will begin with a plan followed by an elevation, a form, the details, at times a model and then finally a building. This approach is a linear one and not necessarily synonymous with the way the creative mind works. The creative mind is capricious it may sometimes tend towards order and at others times tend towards divergence, intuition and irrational procedure.

If the design procedure is permitted to be less rigid, regenerative inspiration may add to the developing design solution at any point. In building design a structural detail may be just as valid a starting point as the consideration of the broader planning issues. For example, a new building material may provide the design inspiration. If this was so it would seem quite ridiculous to begin with the planning issues. It may be far more fruitful to begin with structural concerns, possibly using numerous modelling techniques to test the implementation of this technology on a detail level. As this example suggests, following the path of design inspiration may be wiser than attempting to follow a predetermined design path for no real design benefit.

Design thinking

Both scientific and artistic thought processes are integral to design thinking. In the architectural process they should compliment and balance each other. Various models exist to describe this duality in creative thought. According to Betty Edwards in her book 'Drawing on the Right Side of the Brain' the task of creativity is approached differently by the two hemispheres the submissive right hand side of the brain approaches design intuitively, the left mode or the rational side approaches problems in an analytical, and lineal fashion.

"..each half of our brains may handle the information in different ways: The task may be divided between the hemispheres, each handling the part suited to its style.... The left hemisphere analyses, abstracts, counts, marks time, plans step-by-step procedures, verbalises makes rational statements based on logic.......Using the right hemisphere we understand metaphors, we dream, we create new combinations of ideas." 1.

The internal conflict between logic and intuition, the left and the right, results in the creative response.

There are many fundamental clashes and discords in the way we think. Thought procedures can be objective, rational and methodical, or in contrast they may be subjective, irrational and spasmodic. These processes tend to weigh against each other, struggling for a position of dominance. The designer may push forward, but without a balance the resulting design may prove to be lacking in that essential harmony of form, function and structure that identifies fine design.

Parallel ways of knowing	
intellect	intuition
convergent	divergent
digital	analogic
secondary	primary
abstract	concrete
directed	free
propositional	imaginative
analytic	relational
lineal	non lineal
rational	intuitive
sequential	multiple
analytic	holistic
objective	subjective
successive	simultaneous

(J.E Bogen) 2.

J.E. Bogen is another respected writer to discuss the faceted nature of thought. He identifies a list of opposing terms entitled parallel ways of knowing. This list can directly apply to architectural discussion as the architect requires the capacity to shift from one mode of thought to another. From the abstract to the concrete, from the rational to the intuitive, or from the objective to the subjective. For instance an architect may need to switch from a thought dealing with the stability of a structure, possibly using the intellect, to one that deals with the aesthetic affect of the result, being the intuitive response. These thoughts occur all within an brief instance. We may use the creative side to judge ideas and the rational side to implement ideas and covert them into a useful reality.

In the following quote Leonid Ponomarev emphasises that both approaches need to work together if they are to supply the designer with a complete view. The processes of science and art are complementary, a requirement essential for the production of fine architectural design.

"It has long been known that science is only one of the methods of studying the world around us. Another - complementary - method is realised in art...You can devote yourself completely to science or live exclusively in your art. Both points of view are equally valid, but, taken separately are incomplete. The backbone of science is logic and experiment. The basis of art is intuition and insight....They compliment rather than contradict each other. True science is akin to art, in the same way as real art always includes elements of science. They reflect different, complimentary aspects of human experience and give us a complete idea of the world only when taken together." 3.

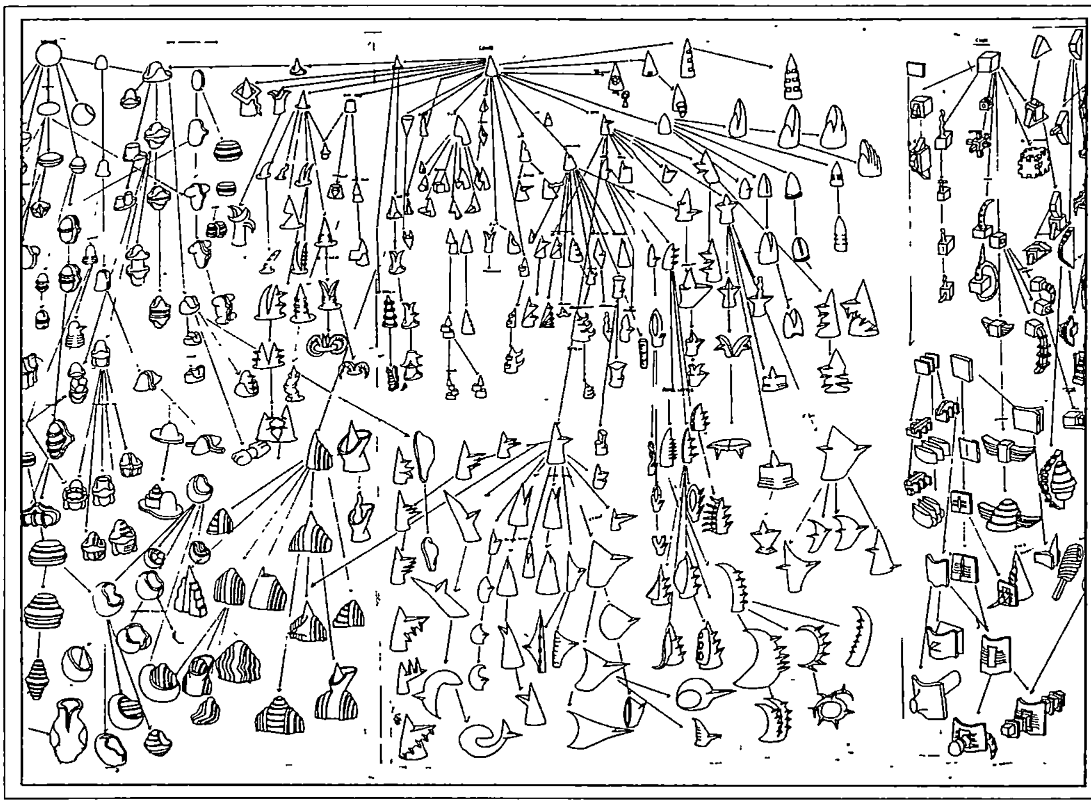
Architectural design requires this type of complementary understanding and the capacity to deal with a wide range of approaches and thought processes. Koestler stresses a similar point of view below.

"...I have been at pains to stress that the artist and scientist do not inhabit separate universes, merely different regions of a continuous spectrum - a rainbow stretching from the infra-red of poetry to the ultra-violet of physics, with many intermediate ranges - such hybrid vocations as architecture, photography, chess playing, cooking, psychiatry, science fiction or the potters craft." 4.

This graphic description clearly supports the opening comments. Art and science coexist with their interconnection producing the duality in creative thought so essential to our thinking.

Design as an evolutionary process

One of the many ways an idea can be developed is via a process of accumulating improvements upon a single model. The idea is adapted and changed in a manner similar to the way Darwin suggested that an animal or plant adapts and evolves. In such a process one idea succeeds the next by a form slightly altered from the original. After a period of time the links between the original and the subsequent result may appear only tentative.



In William Lathem's evolutionary design tree, shown above, simple geometric forms such as a cube a sphere and a cone are systematically distorted or added to in an evolutionary manner. Quite complex shapes result in just a few generations. 1.

Many design ideas have progressed via such a step by step procedure. The following examples taken from P.Steadman's *'The Evolution of Designs'* display objects gaining their characteristic qualities in a cumulative manner. In this process each generation can see further than the next because its predecessor has provided the springboard from which to leap. As Sir Isaac Newton said "If I could see further than others, it is because I stood on the shoulders of giants." 2. or as Leonardo da Vinci wrote; "It is a wretched pupil, who does not surpass his master." 3.

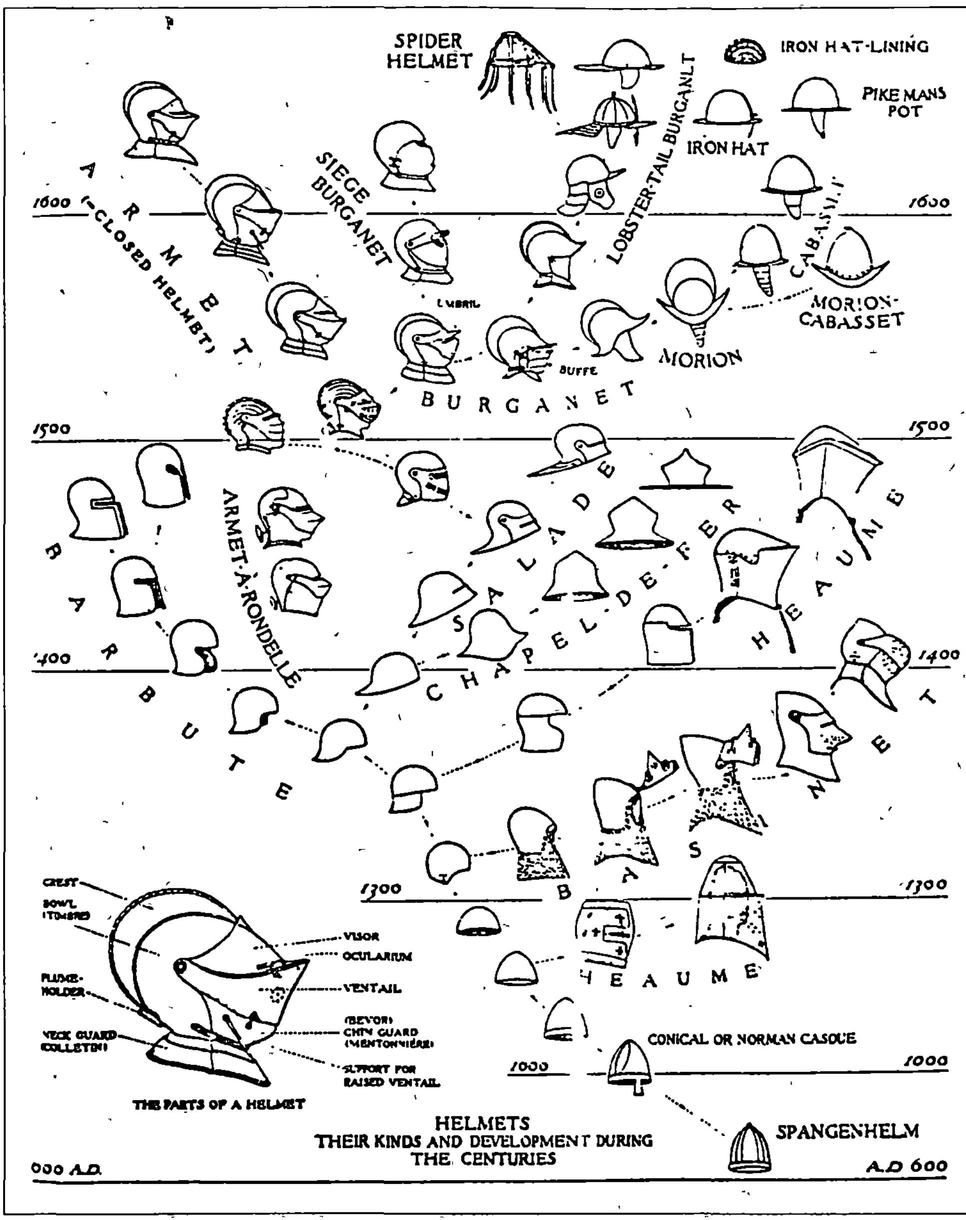


Diagram showing the historical evolution of helmet design. 4.

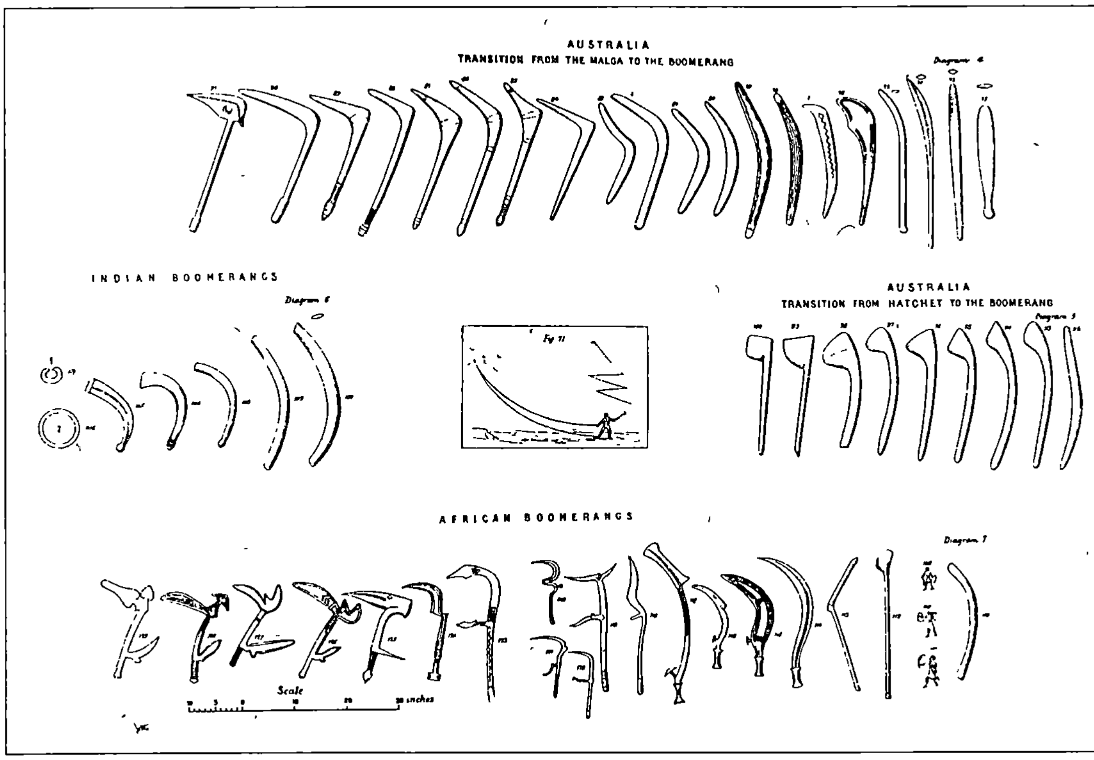


Diagram showing the transition from the malga to the boomerang. 5.

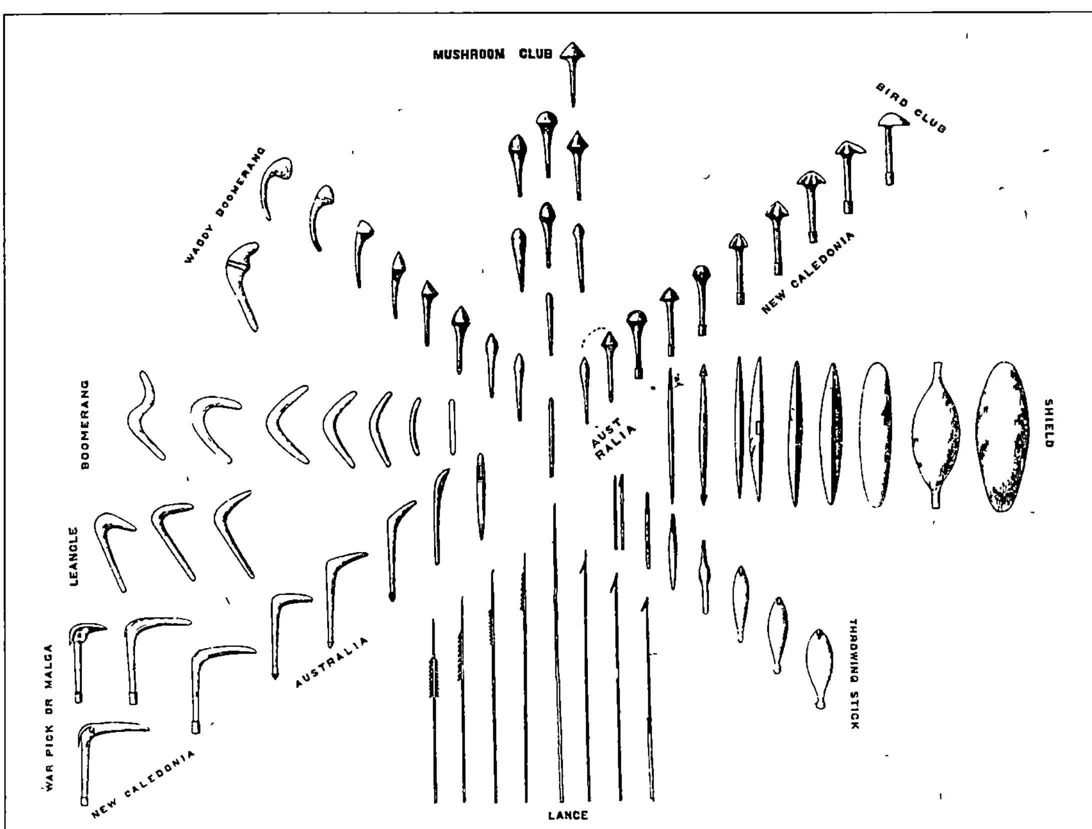
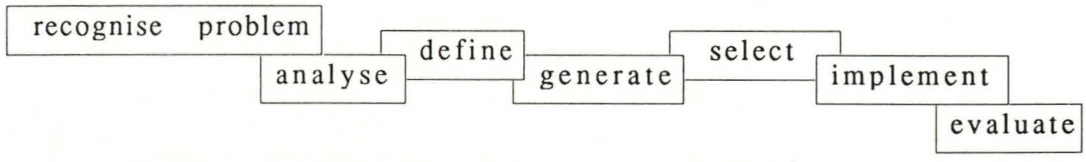


Diagram showing the evolutionary relationship between Australian weapons. 6.

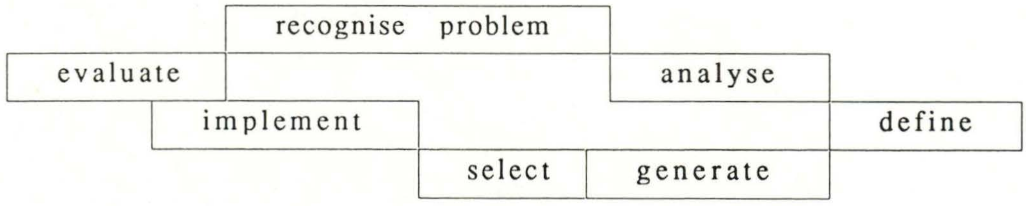
In the process of creative improvement we find that we can never stop improving. We are fools if we believe that what we have designed can not be improved upon. Fine designers are not fearful of modifying their own designs to achieve a better solution. Take for instance Henry Ford who was renowned for piling up one improvement upon another. Before Henry Ford settled upon his design for his first tractor he worked up 871 successive test models. 7. A vital part of the design process is allowing the time necessary to develop and evolve the idea. In design it is a mistake to cut the process of remodification and design evolution too short. We need to realise that we can always make something better, and that even a successful solution can be reexamined and improved upon in a regenerative manner. In every design scenario it is valid to ask the question, *How can I make it better ?*.

Design activities

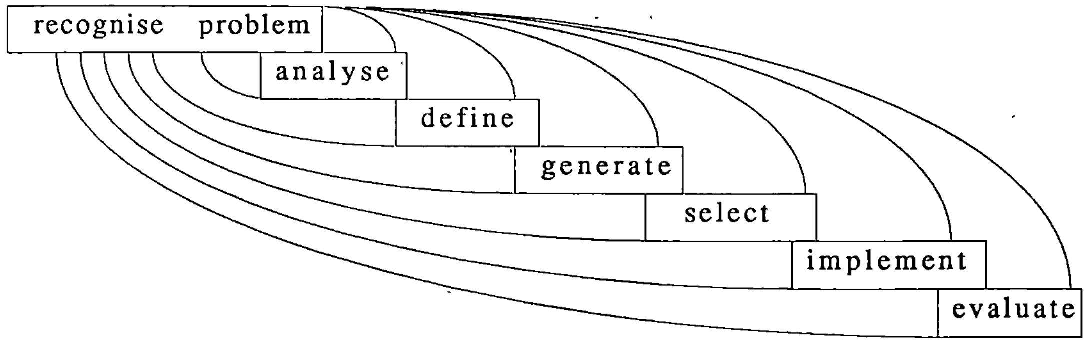
Creative experiences require a heightened level of perception and awareness, they involve originality of thought and expression. In design we experience activities such as, research and exploration, evaluation and experimentation, testing and trials, implementation and assessment, criticism and review. The events that constitute the design process may have no particular order, but they do appear to consistently involve at least some of the following design processes:
• we establish and clarify the problem, • we research essential background information, • we analyse and size up the situation, • we decide upon the main issues of the problem, • we conceptualise and clarify the major goals of the design, • we develop and establish our own guidelines that will direct our decisions throughout the process, • we generate options for achieving the essential goal of satisfying the problem and • we search out possible ways to solve the problem. (Note generating such possibilities is the regenerative phase of the process. In this stage we make decisions and choose from the options and determine the best way to go). In the design process, • we take action and implement our ideas, • we review the implementations, replan and determine the effect of our decisions, testing and deciding upon whether they were successful. This list summarises just some of the events and processes that may occur in the creative event. The selection and order is up to the creative individual. For example, some designers may choose to take a linear approach with a designated beginning and end. A procedure whereby ideas and design processes follow one another sequentially.



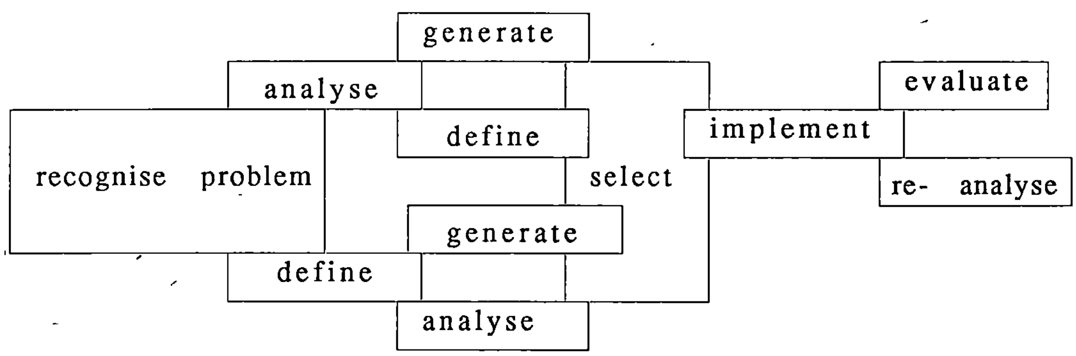
Others may chose a circular process and a pattern of design without an obvious beginning or end. According to this pattern we may reevaluate and redefine the problem after each implementation. The design process evolves ad infinitum, only complete when a sidestep is taken from the circular path of design evolution.



The designer may chose a feedback process which never moves forward without looping back to refer the relationship of a new decision to previous decisions made.

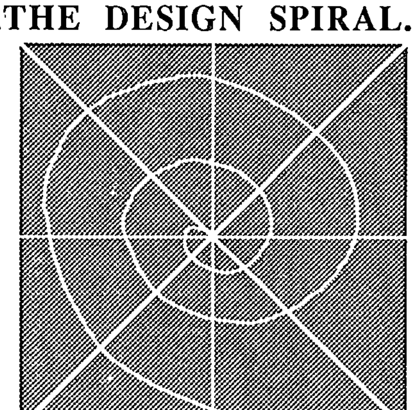


As a fourth possibility the design events may be formed into a branching process where parallel thoughts and comparisons happening at the same time. The ideas branching out and then reuniting further down the track. For example we may analyse and define the problem whilst generating some tentative solutions. Later we may compare the solutions to the defined problem modifying them to suit the determined criteria.



There are many ways to visualise a design process. For the designer graphically expressing this process may be an enlightening act. The diagrams above define only a few processes, and they are obviously not the only possibilities. A model may be devised to suit the way each individual designs. For example I personally visualise my own design approach in the following way.

.THE DESIGN SPIRAL.



*

In the design spiral the process begins with a spark of inspiration, and an initial burst of excitement when the globe ignites and the creative procedures begin. At this point the problem is perceived and we begin a path that will lead to a solution. We follow the spiral path inwards towards the centre of the diagram. In the process we make decisions that narrow our options and direct our creative ideas towards the perceived goal. As we cross the lines that intersect this path, of which there can be any number, we are faced with new information and new decisions to make. We reference our decisions back to those decisions already made and to those that lie on a comparative line of analysis. As we progress deeper into the circle we are referencing our decisions back to a greater amount of information and greater number of previous direction finding choices. This diagram can be drawn at any scale. It can be taken at any pace and we can take as many loops as we like or have time to take. When we reach the central point of the spiral we are considering all the information as a whole. At this point all the research, explorations, evaluations, experiments, tests, trials, implementations, assessments, criticisms and reviews relate to the design outcome.

The 'design spiral' represents how I presently perceive the design method. This is a perception that will undoubtedly change over time. It is essential to recognise that design processes are personally cultivated procedures with forms that will forever change, amorphous and plastic, altering in reference to circumstance and time. By analysing and arranging our present design beliefs into visual reality we may heighten our creative ability and take the creative processes beyond the form of an unconscious and purely internally based contrivance.

Design motivation

For the creative mind to be motivated on to action it must be confronted, or disturbed, by a problem or situation for which it does not have an immediate solution. Inventive people tend to be creatively activated when a problem confronts them for which there are no rules or routines at hand to follow. For example, an artist may be challenged by emotions that he or she cannot express through artistic convention; or a scientist may be disturbed by an observation that can not be accounted for. The motivation to design and the urge to create can be ignited by a challenge, that challenge being the recognition of a quest to devise a solution and create something beautiful or new. The designer experiences a profound sense of personal fulfilment and emotional balance from the realisation of the creative impulse. This experience like a drug may be enough to motivate the designer on to further 'hits' of creative fulfilment. Alternatively the designer may find their motivation in the altruistic act and in the fulfilment of humanity's perceived needs.

It is frequently suggested that humanity responds when there is a necessity and pressure to respond. Plato once said;

"The true creator is necessity, who is the mother of our invention" 1.

Leonardo Da Vinci had the same idea when he said;

"Necessity is the theme and the inventress, the eternal curb and the law of nature." 2.

Before design can occur there needs to be the apprehension of a problem to be solved or an idea to be realised. The diagnosis of the problem is critical in the search for an appropriate solution.

Regenerative solutions will undoubtedly be far easier to find if we have a clear idea of what we are looking for. As John Dewey, the American philosopher, psychologist and educator said "A problem well stated is half solved." 3. and as said by Albert Einstein,"The formulation of a problem is far more often essential than its solution." 4. A clear goal or brief is a significant hurdle in any design process and it is essential if we aim to produce an appropriate design solution. The brief supplies the designer with a clear motivational goal and a defined need. When we establish the need it is often just a matter of time until a solution is found. As Louis Pasteur the French chemist and microbiologist once stated; "work usually follows will." 5.

Many minds foreseeing and tackling the same problem means that there is a greater chance that one mind may solve it. For example we may as yet not know of a cure for cancer or AIDS, but we can be confident in saying that one day one will be found. History has proved this time and time again. Until the 1950's there was no known cure for Polio myelitis. Jonas Edward Salk, motivated by the need to save lives, directed his energy towards finding a cure. After years of research he eventually discovered the vaccine for polio. This vaccine has virtually eradicated the disease in the medically advanced countries of the world.

Physical motivation and even accidents have been known to inspire creative solutions. It is said that Charles Kettering broke his arm whilst crank starting a motor car. It was this experience that set him in search of a non manual starting system. In this example the physical experience of pain inspired design. In architecture the physical experience of a leaky roof or a cold draft may do the same.

We can find our motivation for design in a noble pursuit such as the task of fulfilling the needs of humanity, or we can design for our own visual and mental stimulation simply to occupy our thoughts and to avoid potential boredom. In architecture we can pursue an infinite number of design challenges. We can find our challenge in achieving beauty, or in seeking a higher level of utility. We may be spurred on by the desire to increase efficiency, reduce building weight, or increase the economy of material use. We can strive for architectural purity or spiritual goals. We can seek to follow fashion, create fashion, or pursue new markets for monetary gain. We may choose to follow the environmental movement, pursuing ecologically sound solutions, possibly out of necessity or fear of our own well being. The motivation for design is highly personal but it is essential that the challenge is present.

Technology and Regenerative design

Defining technology

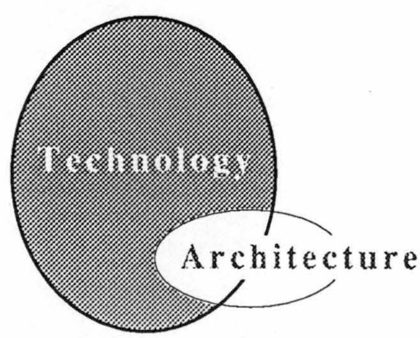
This section will examine how technology fits within the regenerative discussion, attempting to define its relationship to architecture. Additionally, this section shall look at how technology advances and discuss its relationship to the development of regenerative ideas.

The Macquarie dictionary defines technology in the following way;

"**Technology.** *n.* 1. the branch of knowledge that deals with science and engineering, or its practice as applied to industry; applied to science" 1.

The present day definition of technology has far less specific origins. According to Raymond Williams in his book *Keywords*, technology was used from the 17th century onwards to describe a systematic study of the arts. It being derived from Teknologia, Gk, and Technologia, mod. L - a systematic treatment. The root is tekhne, Gr. - an art or craft. He suggests that during the 19th century *technology* became fully specialised to the practical arts. The familiar modern distinction is between knowledge, (science) and its practical application (technology). 2.

Technology is as an essential component of many human activities. One such activity is architecture. Architecture and technology co-exist in an interwoven format. In some areas they tend to be one and the same. For example; structural, constructional or procedural issues can be of architectural as well as technological concern. The following image displays their interconnected relationship. In the diagram architecture intersects technology and a significant amount of common ground is shared between them.



Technology has an enormous range of influence, affecting a greater and greater scope of activities. Like architecture, medicine, art, literature, science and numerous other pursuits have a similar relationship to technology. A part of their composition intimately relates to technology and another part deals with issues extending beyond its boundary.

Alvin Toffler in his well known book 'Future Shock' defines technology in the following paragraph;

"... to most people the term technology conjures up images of smoky steel mills or clanking machines. Perhaps the classic symbol of technology is still the assembly line created by Henry Ford half a century ago and made into a potent social icon by Charlie Chaplin in *Modern Times*. This symbol however is inadequate, indeed, misleading for technology has always been more than factories and machines....technology includes techniques, as well as the machines that may or may not be necessary to apply them. It includes ways to make chemical reactions occur, ways to breed fish, plant forests, light theatres, count votes or teach history." 3.

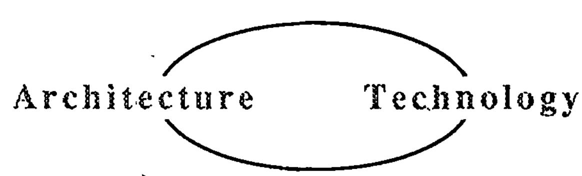
As Toffler suggests, technology includes more than simply the machines and the artifacts that represent it. Technology also includes the methods and the techniques and processes. We can view technology as an object, or we can view it on another level, as a process. To illustrate this point, picture a solar panel; it may be viewed as a glass and silicon artifact, or we may see it as the power generating process. Consider a glossy magazine; we may view it as a collage of information and pictures designed to entertain, (the object), or we may view it as a representation of modern day word processing techniques, a collage of publication, reproduction and photographic technologies. What is clear is the technological process manifests itself in the objects that we create.

A third and vital ingredient in the form and perception of technology is a cultural input. Current social preoccupations tend to control the direction of technology shaping its form. In the 20th century the perception of technology, as Toffler describes, was tainted by heavy industrial machinery. In the 60's, impressions were shaped by moulded plastics, and modernistic forms. By comparison, current technologies are tinted by green issues and tend to be responsive to the environment. These may be generalisations, but they do identify the cultural influences on technology. Technology satisfies the most 'urgent needs' as perceived by society.

A technological advancement may be an improvement in the utility of the object or an improvement in the process that created it. An architectural advancement may also be associated with these goals. For example, a new detail may improve the building's utility, or a new computer may enhance the design process. The advancement of technology is often complex in its ramifications demanding other specific conditions before it will be effective in the hands of the user. For example a computer requires numerous other conditions and supportive technologies to enhance its effectiveness as a design tool in an architectural office.

The concerns and objectives of architecture and technology are very similar. In some instances we can barely separate their development. If one upgrades the other promptly follows. Changes in architectural design are dependent upon the advancement of technology and breakthroughs in architecture directly affect technological research.

Technology affects and inspires architecture - architecture affects and inspires technology.



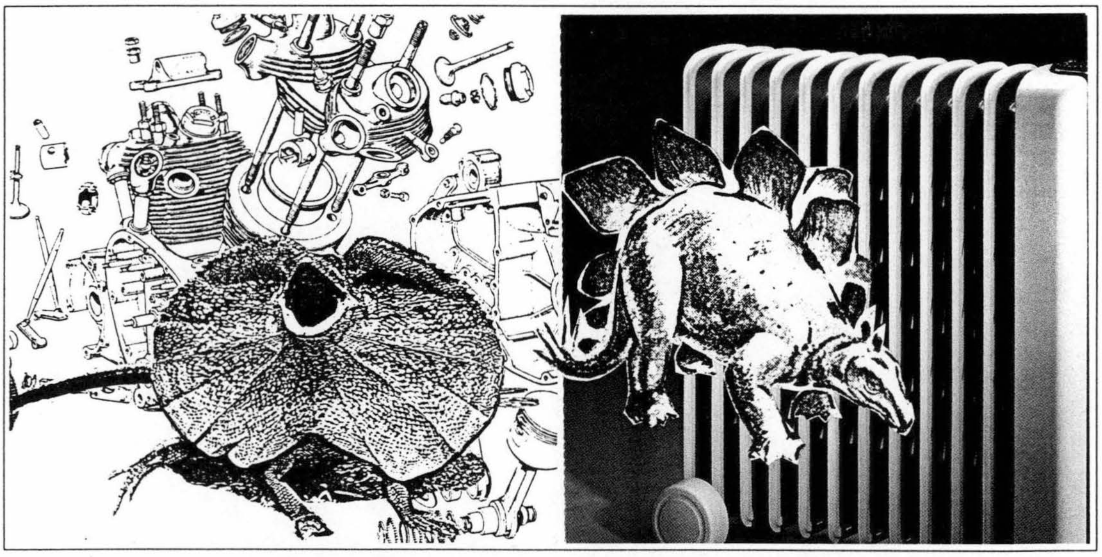
For example, a new technological process or object may inspire architectural design, or in antithesis, the need to carry out a certain task in architecture may inspire the development of a new technology.

Technology is a faceted and complex term, covering a territory influenced by many different pursuits and social directions. It appears that architecture and technology are intimately reliant upon each other, evolving and adjusting in response to social adjustment and change.

Technology and natural systems

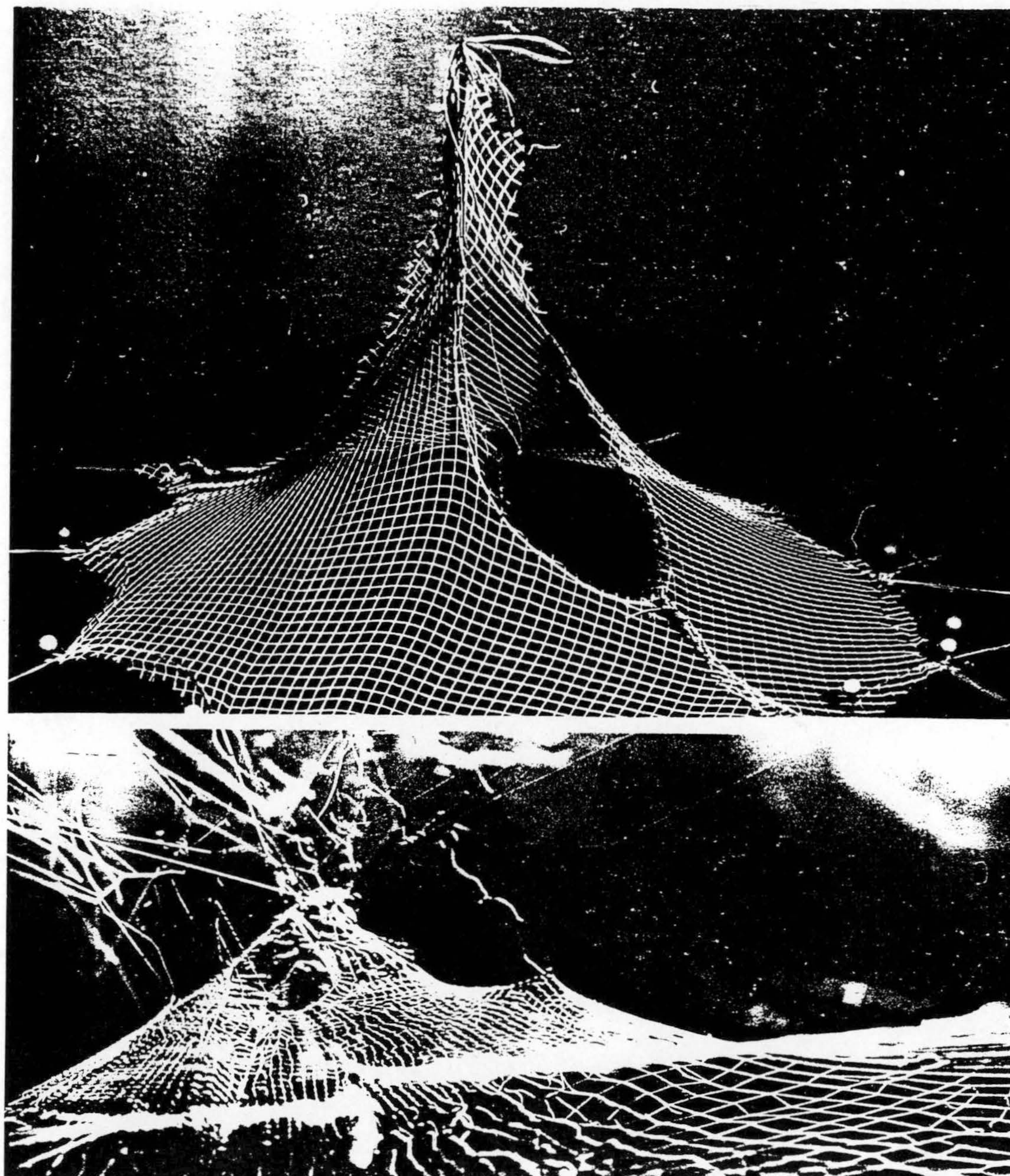
Technology tends to refer to processes and artifacts that are the result of deliberation and intention. This traditional view separates the activities of man from the activities of nature. Human intention forms the dividing line, yet we find that in technology's most recent form such an imposed separation is misleading. A haze shrouds the domain between what is labelled as a manmade technology and what is classified as a natural system. There are numerous examples that are difficult to place under either grouping. For example, there are technologies that combine living structures with manmade structures to form a living machine such as; microbe driven water purification plants, biologically driven sewerage treatment systems or bacteria driven composting machines, all these examples are difficult to place in either group. They represent a new wave of technology, formed in response to a surge of environmental pressure. They are technologies that attempt to slot themselves into existing natural cycles. Such examples are only partially created by humanity and are often little more than the direct application of a natural system to a task. They may be perceived as an attempt to insert and integrate our existence back into the delicate balance of nature. Reducing the violation of the biosphere, caused by the excesses associated with technologies former and environmentally destructive forms.

Many designers have commented upon the profuse wealth of technical inspiration that may be found in Nature, making it their business to translate these observations into design. Architects of this mind set include the world famous; Buckminster Fuller, Frei Otto, Santiago Calatrava and Renzo Piano, all renown for their applications of natural systems to architecture. With this approach in mind we can find countless links between natural systems and technological discoveries.



1. The images above all have something in common. They represent a fundamental principle of nature, the principle being that heat is released more rapidly from an object with an increased surface area to volume ratio. The blades arranged on the back of the dinosaur Stegasaurus released heat from the reptile's body in the same way as the blades on a motorcycle engine do. The skin surrounding the neck of a frill necked lizard and coils of a radiator, are all 'designed' to do the same. The inventors of these technological equivalents may not have thought of these particular analogies, as there is an enormous array of animals and plants that employ this fundamental principle. It is almost certain that these cooling systems were derived from similar observations.

As is often the case, what we assume to have been entirely formulated by humanity is present in nature. The designer may chose to capitalise on this, and via a regenerative process set about consciously interpreting nature, directly applying the principles to design.

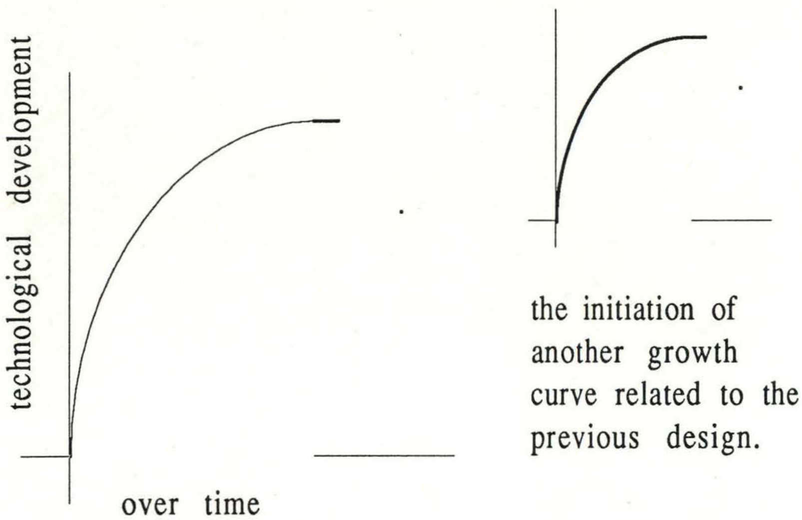


Architectural model and a spiders web. 2.

How does technology advance?

The time spent advancing a technology can often be equated with its performance. The greater the time spent on improving an object or process obviously the superior the result will be. Objects of design that have been refined and improved upon over a longer period of time are often more difficult to improve upon than those that have had only a short period of design evolution. This concept may be visualised as a hyperbolic curve. In it a phase of rapid development in the early stages is followed by a period of much slower improvement, tending towards a limiting optimum.

A design growth curve

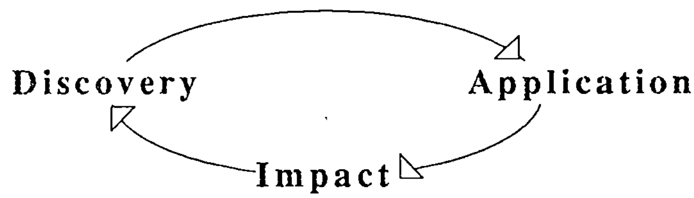


Consider for example developments in sealing compounds, sail cloth, composite board products or even the humble brick. These building products have all initially experienced rapid periods of technological development followed by more gradual periods of design evolution. As the diagram indicates the growth path of a technology may be viewed as a series of such curves. Often an initial growth curve is followed by a subsequent growth spurt that may relate to the discovery of a new process or material. For example, recycling processes, may inspire a fresh growth curve in brick production. The initial concept, in this case the brick, may inspire an increasing number of new possibilities and technological growth curves.

On a larger format technology may be seen to advance via a reflective process. In such a process a *discovery* feeds an *application* and results in an *impact* that has the potential to feed another *discovery*. Every new technology has the ability to inspire and aid in the development of another technological idea. As Alvin Toffler states,

"The reason for this is that technology feeds on itself. Technology makes more technology possible, as we can see if we look for a moment at the process of innovation. Technological innovation consists of three stages, linked together into a self reinforcing cycle. First there is the creative feasible idea. Second, its practical application. Third, its diffusion through society. The process is complete, the loop closed, when the diffusion of technology embodying the new idea in turn, helps generate new creative ideas." 1.

This passage describes a regenerative cycle, a process of development that reoccurs at infinitum. The proceeding diagram represents how technology can advance under such an assessment. This view considers the procedure rather than the rate of growth, or its goals. The result of this process may be hard to predict, and may only be judged with the benefit of hindsight. The dead ends and failed experiments can stimulate us to rethink our basic premises and perhaps embark on a design journey in another direction.

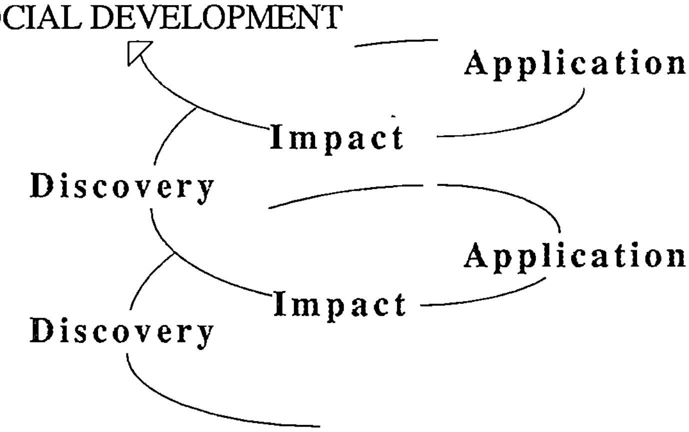


2.

"Discovery. Application. Impact. discovery. We see here the chain reaction of change, a long, sharply rising curve of acceleration in human social development." 3.

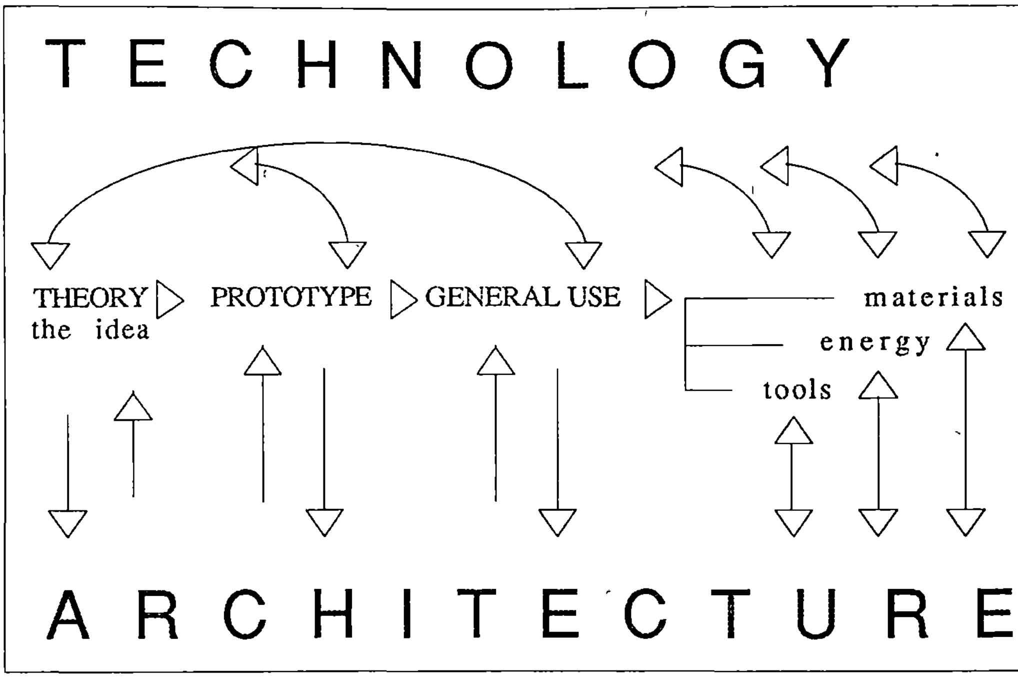
In a more complex visual representation the process can be viewed as a three dimensional spiral. The plan view of this spiral is similar to the diagram above but in section it travels upwards towards, as Toffler writes, a goal of human social development.

HUMAN SOCIAL DEVELOPMENT



4.

Such a process of technological development is not a closed event. Periodically other discoveries are injected into the cycle, giving it the energy boosts it requires to continue. These inputs closely influence the resulting outcome. In the development of technology information is simultaneously drawn inwards and spun outwards. On its outward path the technological discovery may find an architectural application. A technology may be in the form of a theory, a prototype or possibly a tool when it is transferred to architectural design. In exchange an architectural discovery may be drawn back feeding technology. The following diagram attempts to specifically explain the development of technology in relation to architecture.



The transience of technology

"It is vital to understand, moreover that technological innovation does not merely combine and recombine machines and techniques. Important new machines do more than suggest or compel changes in other machines - they suggest novel solutions to social, philosophical, even personal problems. They alter man's total intellectual environment - the way he thinks and looks at the world." 1.

The changing character of technology has a profound affect on all aspects of our environment. Technology presents the architect with many new opportunities, and enables us to view past technologies in a totally different light. Concerning the transient nature of technology and information Toffler writes;

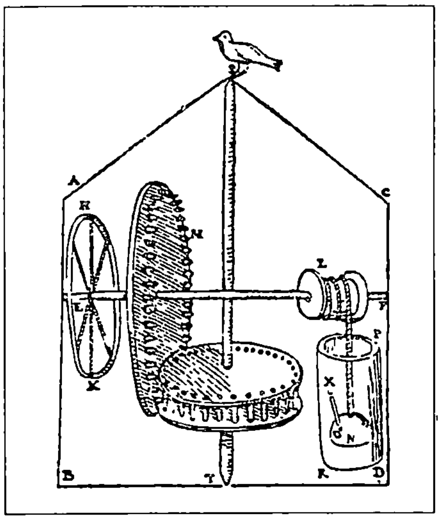
"We have witnessed the virtual disappearance of the solid old durable leather binding, replaced by first cloth and later paper coverings. The book itself is much like the information it holds, it has become more transient." 2.

Similarly in architecture past and present technologies can seem equally disposable. For example the masonry arch developed as the means to span an opening with a unit sized compression material is now seldomly utilised as it has been replaced by new technologies, such as the steel lintel. The mortise and tenon joint is another technology that is rarely used now that nails, screws and bolts are available to effectively complete the task.

The perception that a new technology is always better than an old one is a misconception. For the designer it is often too easy to become so involved in a process of looking forward that we forget to look back to the wealth of knowledge behind us.

There are many ideas and technologies that have been placed on the scrap heap, and that are thought to be of little use in a high-tech society. The reconsideration and regeneration of such ideas may supply the architect or the designer with a wealth of design inspiration. In such a jumble of discarded designs we find that for the receptive mind, the number of reusable ideas is as numerous as the objects found. If a design does not have the capacity to inspire us favourably, it may remind us of what not to do. A point worth stressing is that the architect can extract a design idea from almost anything found.

A regenerative approach promotes the analysis of discarded designs and the reuse of the ideas embodied within them. Today we find that we are often looking back to those ideas that were sometimes more sound than the ones that replaced them.



An early notion of a mechanical clock is to be found in Hero's *Spiritalia*. As the weighted cord unwinds, a gear mechanism moves the shaft that the bird is attached to, allowing it to follow the sun's movement. 3.

There are many technologies that most designers would consider redundant yet they are still valid today. For example, many would believe that the mechanical process of clockwork is a technology of the past. This belief has been proven incorrect by the recent use of clockwork mechanisms to generate power for a transistor radio. The result is a device that has its own autonomous and environmentally friendly energy source. The wind up transistor radio does not require the highly toxic batteries that have only a short life and have proven so difficult to recycle or dispose of safely. The design motivation behind its development was a set of limitations, both environmental and contextual. The clockwork radio was purposely designed for remote locations where it is expensive to obtain and safely dispose of batteries. The amalgamation of these ideas is the result of a regenerative process that sifts back though knowledge to seek inspiration. The logic embodied in the process can be admired in the solution.

At first one may believe that the unification of mechanical power and radio is a new idea, but this is not so. During the second world war battery operated devices were replaced by more reliable mechanically operated devices. Radios, lights and torches were powered by hand levered systems, pumping devices and even bicycles. Such low energy solutions were invented as a response to war time shortages. In the 1990's we also desire to use less battery power. Even though this is for a set of different reasons the same solutions could be reapplied to 90's design problem. The analysis of low energy war time devices may open up an exciting array of design possibilities. It could lead to the rediscovery of ideas with the potential to greatly inspire low energy design. One such idea is the mechanically operated torch. This is a brilliant idea awaiting reintroduction to an ecologically sensitive market. Torches at present are highly reliant upon batteries. Why not, instead of battery power, have a wind up mechanism. The mechanical torch is an example of a technology that is on the brink of its existence. It may be appropriate to recycle and mass market this design solution in todays design context.

In discussing this path of design thought a little further, we may question, what other solutions may have been devised if lead acid batteries were never invented. We know that there are countless other ways to generate a small supply of power and most would be far more appropriate to our time. The biological battery may be another answer to the fact that we can no longer justify the use of traditional batteries. In contrast to the previous energy solution the biological battery is a regenerative response that looks towards a natural model, rather than an artifact, for inspiration. The biological battery is created from natural cells, the idea derived from a study of the way certain species of eel store electricity. Like the wind up radio, the biological battery is a regenerative solution. The generative design core of the response has been observed beyond the normal view of the problem, and transferred from one situation to another.

In the technological race, it is at times advisable to sidestep from the speeding train of thought to contemplate past ideas to their full extension. It may be possible to generate numerous appropriate and exciting solutions by reconsidering earlier models. For the architect technology is undoubtedly a force that requires a degree of restraint and directional manipulation. We essentially require a moment to consider the broad view and the impact of decisions within the greater context.

The final decision upon what technology may be appropriate to a design task is complex and ultimately dependent upon the design circumstance. Successful decisions may be made upon economical, social, production based, or environmental grounds. Cultural acceptability may direct design decisions and surrounding infrastructure may influence its production. For example, the refinement of the combustion engine, the Sarich engine, may be easier than the development of an electrically driven motor, as so much is invested in oil technologies. Design decisions may in turn be swayed by environmental issues. Other available technologies may influence the outcome, or the cost, or complexity of the design may spell its own doom. There are obviously numerous unavoidable and variable limitations on design that may influence the resulting architectural or technological product.

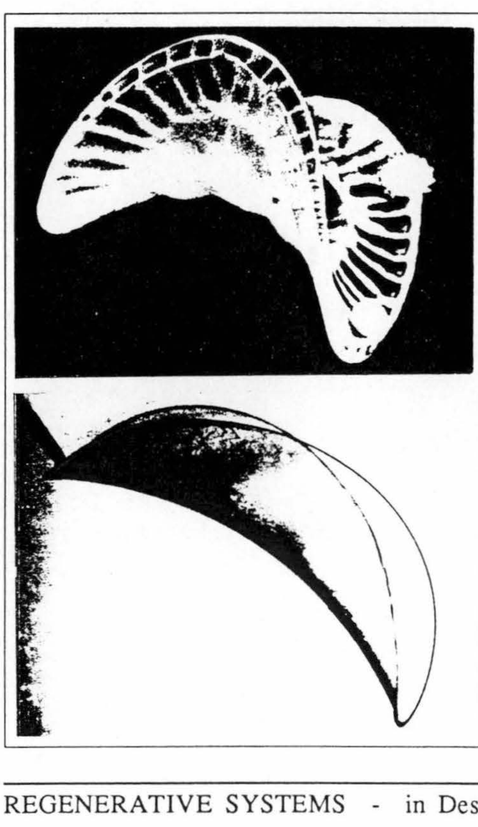
Section B:
Analysing the sources for design inspiration

This segment analyses a range of design sources. The intention is to bring into focus many natural and artificial examples that may prompt design thinking. It is important that the designer is aware of the possibilities, and the way by which inspiration may be drawn from these generative references. It is suggested that these sources are integral to the regenerative process. The discussion is divided in two parts; the first being natural inspiration, the second being inspiration from artifact. To differentiate the categories reconsider the transistor radio; the use of clockwork mechanisms may be viewed as an artifact inspired response, whereas inspiration from nature may lead to the production of biological batteries based upon electric eels.

The discussion covers: structural, process related, functional, material, economic and visual interpretations of 'natural' and 'technological' origin. The analysis also identifies the emotive or rational grounds by which ideas may be sought and applied. The section concludes in an open ended diagram that summarises the possibilities. The diagram is intended to clarify less conscious design responses and aid in the search for comparative design ideas with the potential to inspire a regenerative design process.

It is important to note at this point that the distinction between nature and artifact is by no means clear cut. The categories are tentative, and the interconnections need to be emphasised. The issue of their interrelationship is well considered. Quoting D'Arcy Wentworth Thompson:

"The search for differences or fundamental contrasts between the phenomena of organic and inorganic, of animate and inanimate things, has occupied many men's minds." 1.



Wire bubble and an organic structure. 2.

To identify the distinction between natural and artificial forms consider these images. One is organic and made from living matter, the other inorganic and made from wire and soap. One is clearly natural the other unmistakably artificial yet both examples clearly display a consistent form, one notable for its structural efficiency and aesthetic character. The models may be different in composition yet they are similar because they are both subjected to the '*laws of nature*'. They exist under the umbrella of the natural world, which affects inorganic or organic models in a parallel way, blurring the distinction between. Either form may provide a dynamic starting point or generative model for the designer concerned with comparable, structural or aesthetic design issues.

Natural inspiration

Natural inspiration

"..... natura optima e divina maestra di tutte le cose"
'nature is the best and divine teacher of all things." (Alberti) 1.

Nature is undoubtedly at the core of conceptual understanding. Its presence affects the development of our perception and therefore tour resulting actions. Nature is a prime source of inspiration and has been viewed by many of the world's greatest thinkers as the 'divine teacher' in a spiritual, cultural, social, technical and aesthetic sense.

"If we consider the beautiful machine of the world, with how many wonderful ornaments it is filled, and how the heavens, by their continual revolutions, change the season according as nature requires, and their motion preserves itself by the sweetest harmony of temperature; we cannot doubt, but that the little temples we make, ought to resemble this very great one..." (Palladio) 2.

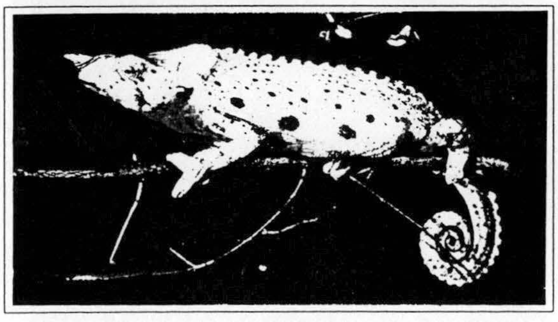
In the passage above Palladio clearly expresses a desire to establish harmony between the natural and the made object. A process that attempts to unify the two worlds, through design is particularly relevant considering the present environmental pressures upon our existence.

Frei Otto also supports the view that nature and design need be brought closer together;
"Art and artifact are still regarded as the opposite of nature and the natural. But these opposites are outdated .... The new plurality leads to the unique building, it does not result in chaos, but leads to a strengthening of those trends that will bring about a higher level of integration and adaption of building to nature and mankind." 3.

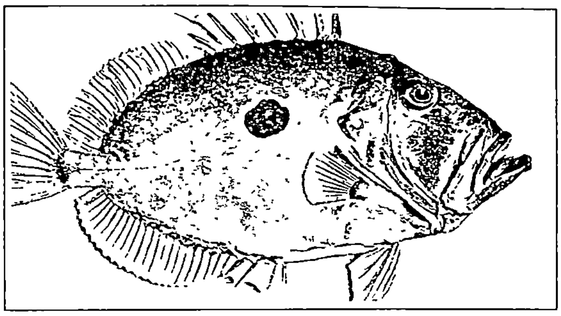
This enduring theme has been the source of much discussion and interpretation. This suggests that such an approach and source of ideas for design is most worthy of examination.

For the designer, the riches of nature are inexhaustible. A countless number of technological ideas and inventions have been based upon natural devices. For example;

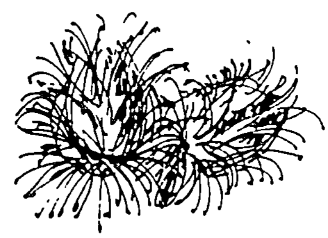
- Modern automatic focus and exposure in cameras was patterned on the workings of the human eye. 4.



- Camouflage and concealment principles for military purposes have been evolved from the observation of moths, chameleons and many other types of animals and plants that have used the art of camouflage to hide themselves for millennia. 5.



- Submarines imitate the principle of a fish's swim bladder for underwater ballast. The fish inflates and deflates its swim bladder with gas to change its depth in water. The submarine carries out a similar process. 6.

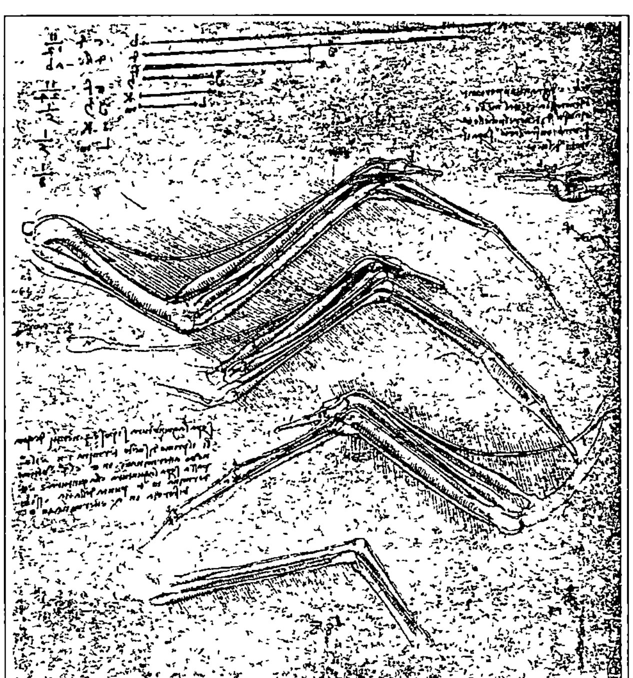


- Velcro was invented by a Swiss engineer who made a careful study of the clinging burdock burr which grabs on to fabrics. 7.

As these examples suggest, nature has an unprecedented and unlimited potential to enlighten mankind.

There is a great deal of logic behind seeking inspiration for design from nature. This logic is founded upon the belief that if these processes, structures and principles have worked so well in nature for so long, why shouldn't they have successful design application. The interpretation of the burdock burr is a prime example of a natural structure successfully converted into a man made technology. The burr has a renown and pestilent reputation based upon its ability to stick to clothing. The interpretation of its structure into technological form has achieved a similarly successful result.

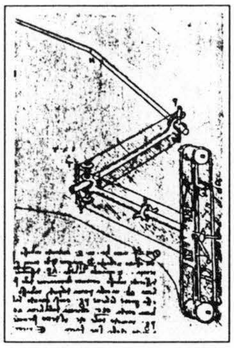
In a regenerative process the natural equivalent is used as a conceptual model. We may collate information that can guide the creation of the design interpretation by studying how the natural model succeeds or achieves the desired effect. For many technological ideas there is a natural model to be found. The recognition of such a link clearly opens up a conceptual bridge between what we label as artificial or natural.



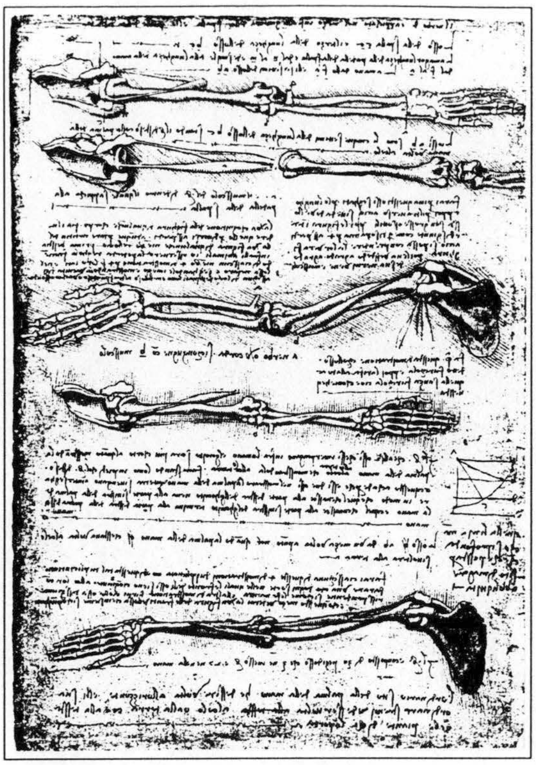
Studies of the anatomy of a bird's wing and flight (Leonardo da Vinci) 8.

Leonardo da Vinci, the notable artist and inventor, understood the immeasurable potential in the scientific analysis and observation of nature. He recorded in his notebooks hundreds of detailed drawings of birds, fish, human organs, human figures, plants and so on.
Leonardo's secret in the creation of a deluge of inventions was the study and interpretation of Nature. He analysed nature in minute detail and then recreated what he saw in his inventions. Many of these inventions proved to be centuries ahead of their time. A success rate as high as Leonardo da Vinci's apportions a

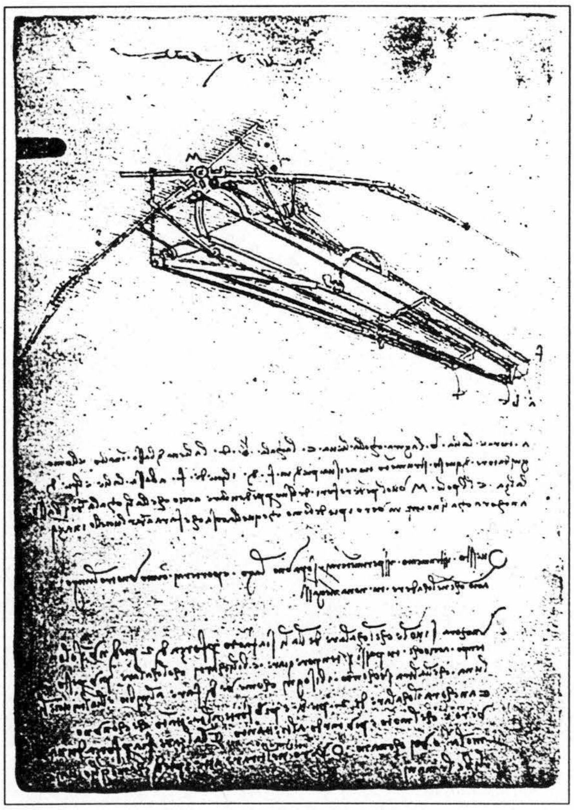
great deal of support to the suggestion that nature is a provocative source of auspicious incitement for regenerative design.



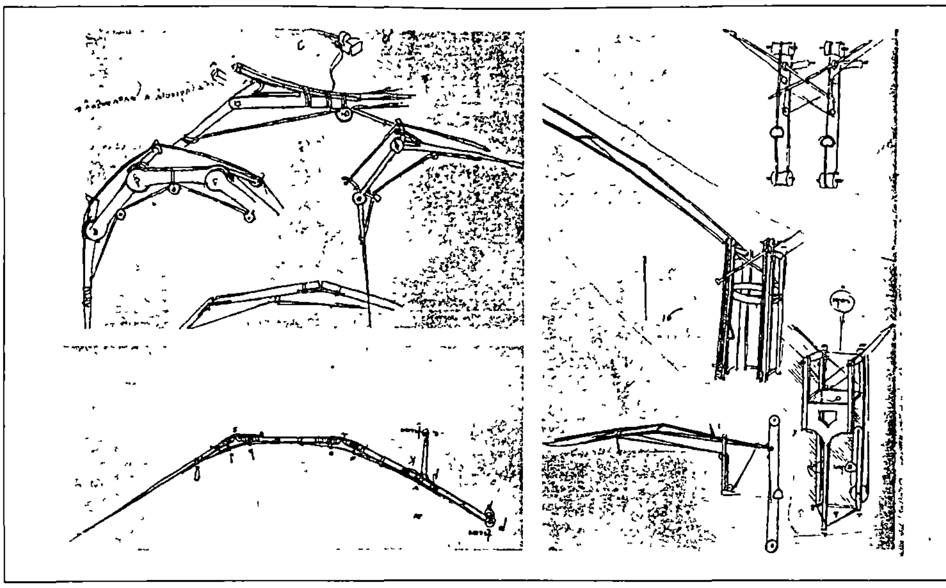
Mechanism for rotating wing. 9.



Studies of the arm showing the movements made by the biceps. 10.



Design for a flying machine. 11.



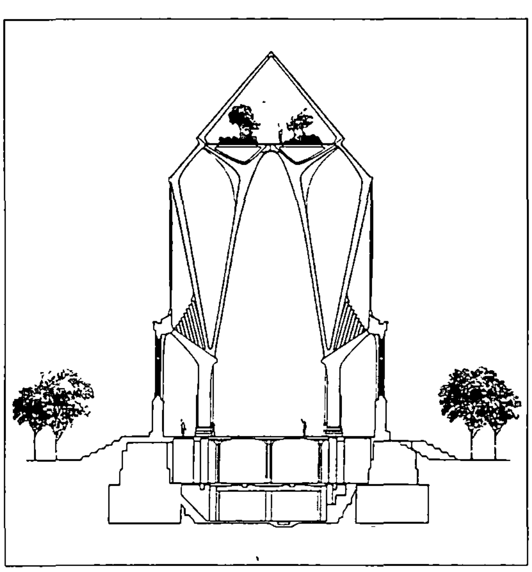
left above: Flexion distension of wings, left below: System of automatic flexion and distension of wings, right: Device for manipulating wings. 12.

The structural interpretation of natural forms

It may be observed and is often suggested that almost all major structural forms and structural technologies are presented to us in the world of Nature. These surrounding forms and systems may simply await observation and interpretation by the perceptive architect or designer. As Santiago Calatrava suggests in the passage below the mechanics of nature can provide the incitement for structural contemplation and the inspiration for a comparative design application.

"Working as an architect or engineer naturally requires a source of inspiration .... A cantilever is the simplest engineering representation of a tree. The restraint is represented by the roots of the tree. Both obey certain laws of bending movements. So however most engineers think about it. I believe that the professional activity of an engineer lies mainly in the development of analytical models which describe nature in a realistic way." 1.

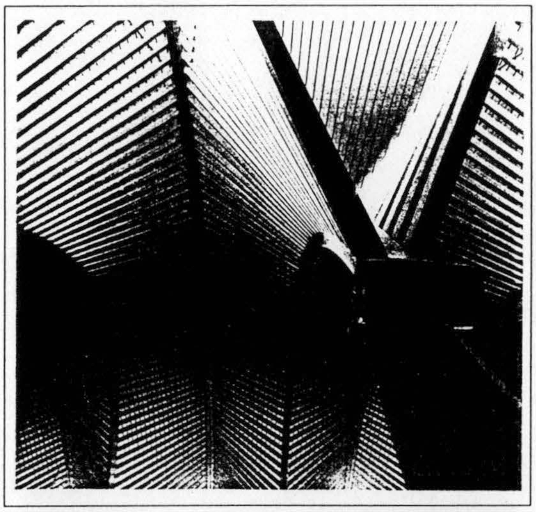
'Biomechanics' is a term employed by Calatrava to label this structural translation of nature.



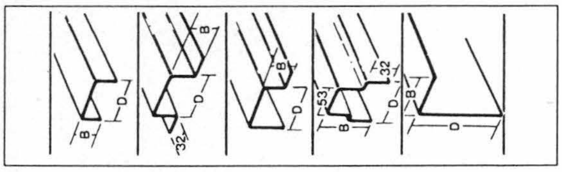
S. Calatrava, St. John the Divine, New York 1991. 2.

There are many structural principles that may be derived from what we naively view as the simplest of natural structures.

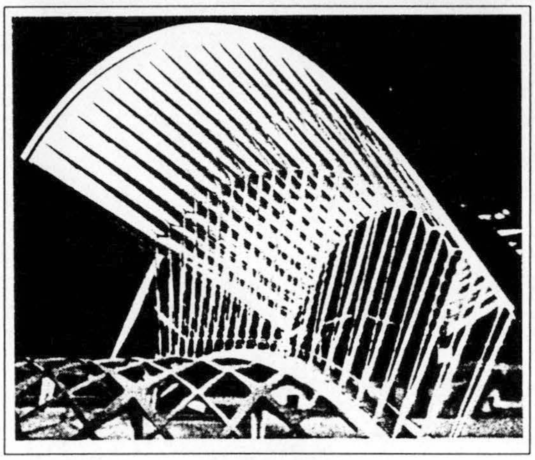
For example a humble blade of grass, upon first sight possibly overlooked for its ordinariness, may provide the designer with a wealth of technological knowledge directly applicable architecture.
Consider the following images and annotations exploring the potential of this generative model.



- The cross sectional shape of a blade of grass increases its strength. The 'V' profile has numerous architectural applications and is highly applicable to the production of high strength to weight ratio building materials. 3.

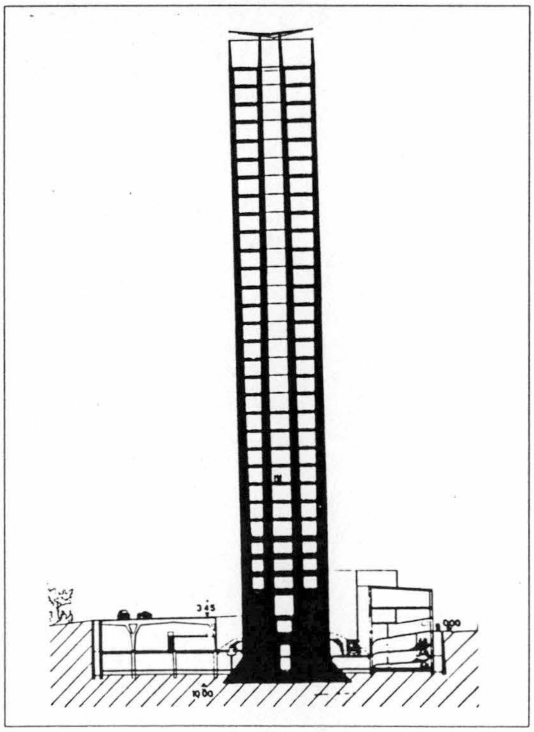


Santiago Calatrava's Wohlen High School hall roof demonstrates a comparable V profile (1984-89). 4.

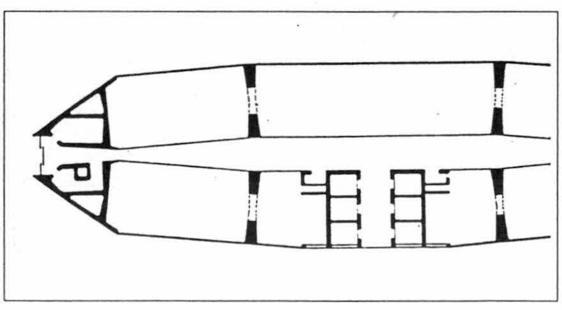


- A blade of grass has a tapering profile that responds to structural load. The grass is thick at the base and fine at its tip. An architect may find inspiration in this observation possibly applying it to the construction of a canterlevered deck, awning or roof. This structural interpretation may be compared to many of the structural elements designed by Calatrava.

S. Calatrava, Lyon Airport Railway Station. presents a comparative tapering profile. 5.



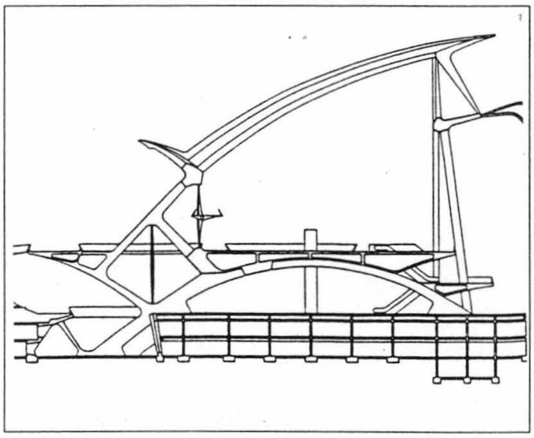
- A thick ball of roots forms a weight for the cantilever. The roots grip the earth and use friction to support the structure. This is not unlike the steel driven piers on a sky scraper. We can readily interpret foundation making systems, applicable to building design, from the examination of the root structure of a cantilevered plant.



Nervi, Pirelli. Building section, Massive at the base and slender at the top. 6.

- A blade of grass has a skeleton with a main spine and a decreasing order of supports to stiffen the framework. The network of members can be compared to a structural network of reinforcing and thickenings in a concrete slab.

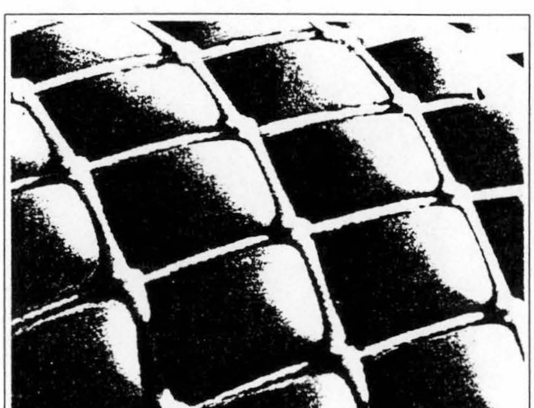
The underside of this leaf can be compared to the underside of the concrete car ramp in the Fiat factory, Turin. 7.



- The spine of a blade of grass has an ellipse profile with a thickened base and ridge. This finer level of profile manipulation once again increases the strength of the member.

Observations such as these and many like them have an enormous potential to inspire building design.

S. Calatrava, Section of the Science Museum, Valencia. 8.



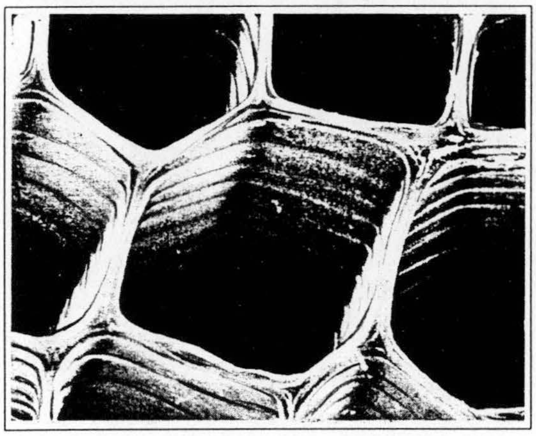
- Pressure filled or pneumatic structural principles may be interpreted from the blade of grass.

An increased pressure within the cell structure helps the form retain its stiffness.

A balloon constricted by a net presents a similar structure.
(Frei Otto) 9.

- The blade of grass uses flexible load shedding principles and aerodynamics to reduce loads upon the structure. Rigid forms that resist all types of movement are more likely to suffer structural failure than flexible forms that allow for a certain amount of movement within their construction.

The modern dome tent actively resists wind loads by a comparable process of flexible load shedding. 10.



- Cellular construction reduces the weight of an entire structural system. This is evident in organic material and in may building products such as aerated building blocks. On a larger scale trussed structures conform to the same philosophy. The high strength to weight ratio of many organic structures may be highly applicable to architectural design.

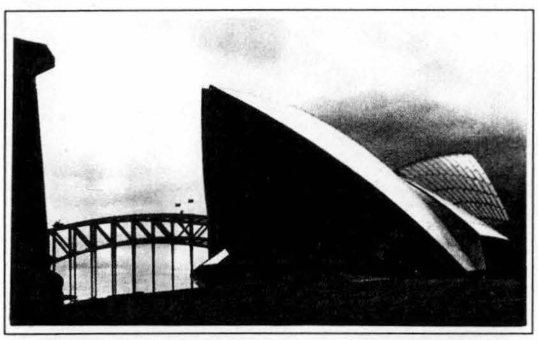
Cellular wood section
(Frei Otto) 11.

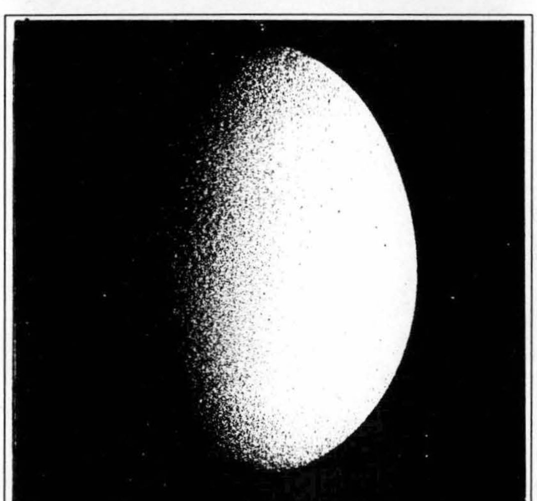
As these examples illustrate there is a seemingly endless number of structural technologies that may be interpreted from even the simplest of natural forms. The previous observations and many more like them may be directly applied to architectural design.

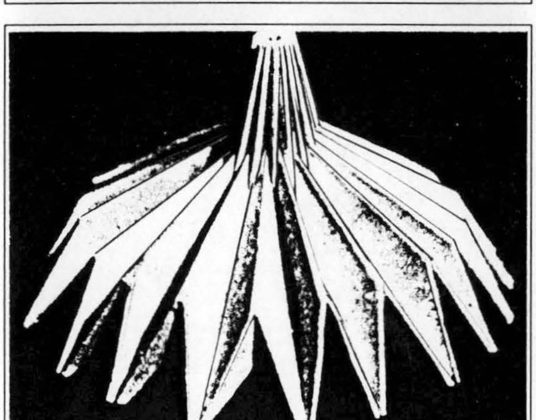
In the case of the blade of grass both analytical and emotive observations have inspired the discovery of technical knowledge directly applicable to building design. Frei Otto, a highly respected participant in the search for structural ideas based upon nature, passionately identifies his own emotive stimulation. Renzo Piano states; 'Lightness is a concept I fell in love with', in doing so claiming his thoughts to be of passion rather than reason. Even though Frei Otto and Renzo Piano clearly identify an emotive basis to their regenerative discoveries, the design applications appear to take on a technical form. This presents a complex duality. A process whereby the inspiration for regenerative design may be emotive and aesthetic yet its application unquestionably scientific and technical. Consider for a moment the skyscraper, one of todays modern symbols of technology, there are certainly strong emotive and rational reasons for the construction of such an edifice. The example of the skyscraper suggests two things; it suggests there may be a strong emotive element behind the pursuit of technology, and also what draws attention to a regenerative idea may be very different than what is drawn from it in the way of technical information. Numerous aesthetic and emotive forces are also involved in the reinterpretation of lightweight natural structures. Lightweight structures are undoubtedly constructed for more than rational incentives. In the emotive sense lightweight structures appear to defy our understanding of natural forces, prompting the viewers preconceptions to alter. A lightweight structure may excite the observer, it may captivate the imagination, and challenge the viewer to consider why it does not collapse.

The intricate and detailed natural structure tends to appeal to our tactile senses. We all enjoy the experience of touching a fragile object. Maybe we desire to touch it to reinforce our visual perception of the object and determine whether our eyes are fooling us. This desire may also stem from a desire to test its fragility. The inquisitive and determinate character of humanity has lead many of us to the destruction of a flower or spider web through a process of structural examination.

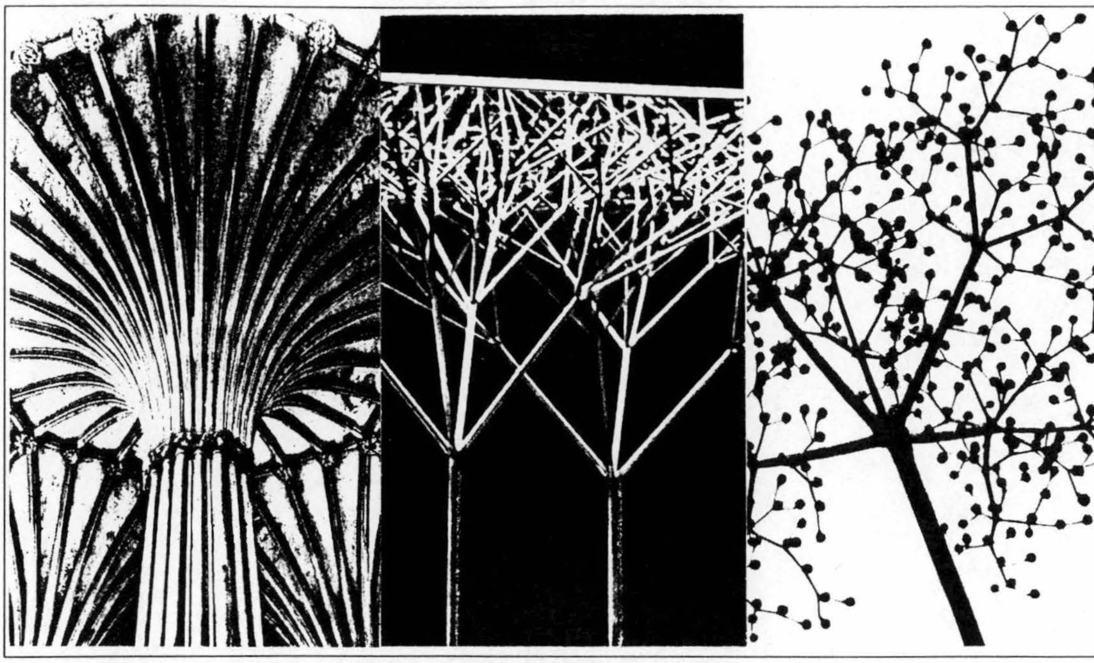
Every structural problem has many possible natural models upon which to base a regenerative solution. The designer may find several different examples in nature that are all applicable to their design intentions. The selection of a model or models is a significant stage in the design process as it will tend to influence the whole design programme. Throughout the design programme the architect will need to re-evaluate their choices, testing the the models appropriateness or referring back to it for more technical or aesthetic design information. The best solutions will retain their aesthetic as well as their structural integrity. For example Joen Utzon in the design of the Sydney Opera House struggled to retain the integrity of the shell structures as numerous constructional problems arose. It has been suggested that he solved the problem by reverting back to a natural model, that being the skin of an orange, from which all the shapes of a slightly modified roof form were sliced and rearranged. 12. The final solution retained its structural integrity as well as aesthetic purity. In this case the structural model directed the decisions and influenced the aesthetic issues. 13/14. A high strength to weight ratio is a common ingredient in many natural structures. The image below present another design option modelled upon a natural structure. 15/16. These images suggest that ribs or folds







increase the strength of a structure. (An observation also applied to the design of the Sydney Opera House). In this case Frei Otto has converted the observation and analysis of a folded natural structure, a mushroom, into a folded paper structure. The next step would involve the translation of such an observation into folded plates or structural ribs for a building.

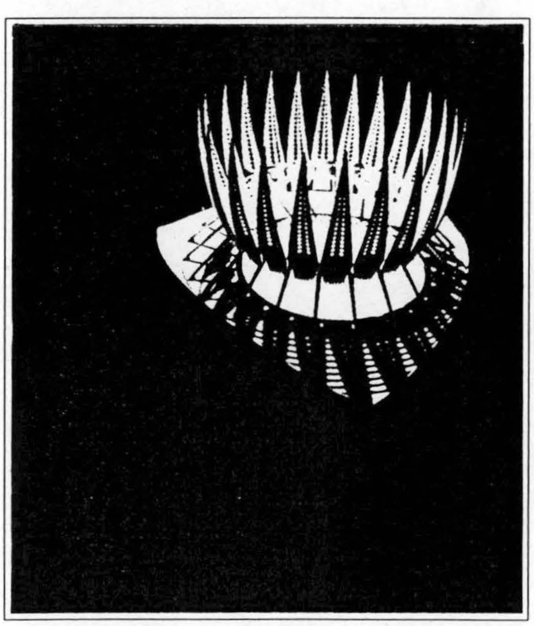


Ribs of a gothic vault, model of a modern tree structure, Umbellate flower of the elder 17.

The potential for the use of nature as a structural library is overwhelming. The resource provides the architect with an unlimited range of models upon which to base structural thinking. The interpretation of the many structural forms found in nature may be personal or conventional. The designer may admire and reinterpret natural structures for rational or emotive reasons, including incentives of visual or tactile delight, the structural challenge, or the goal of built economy.

The interpretation of the working parts

Nature presents the designer with numerous working features, such as moving parts or functional design features, that may be applicable to architectural design. As a structural model may influence the design outcome in either an aesthetic or technical sense, so may the working parts of a natural structure.

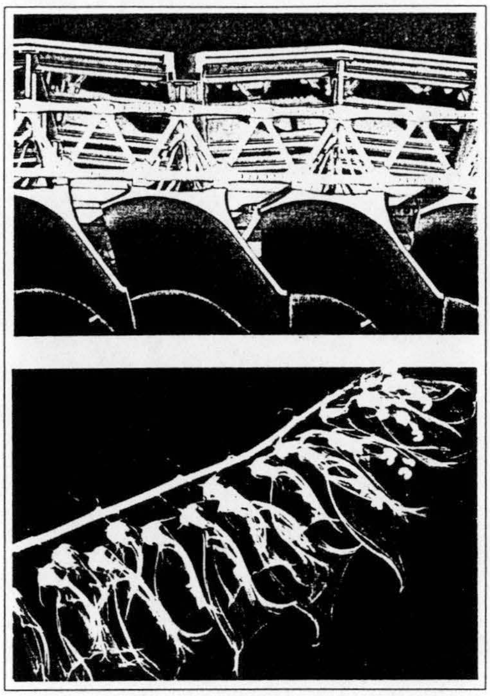


Consider the following examples;

Calatrava's performance space designed for the 700th anniversary of the foundation of the Swiss Confederation directly recalls the working forms of nature.
The structure draws inspiration for its design from a water lily.
The building designed for lake Lucerne floats on the surface like a lily and opens and closes with the same excitement and emotive performance value as the flowering plant.

1.

The Houston Gallery designed by Renzo Piano to house the Menil Collection in the U.S.A. is another example that identifies in an emotive sense the working aspects of nature, applying them in their technical form to architectural design.

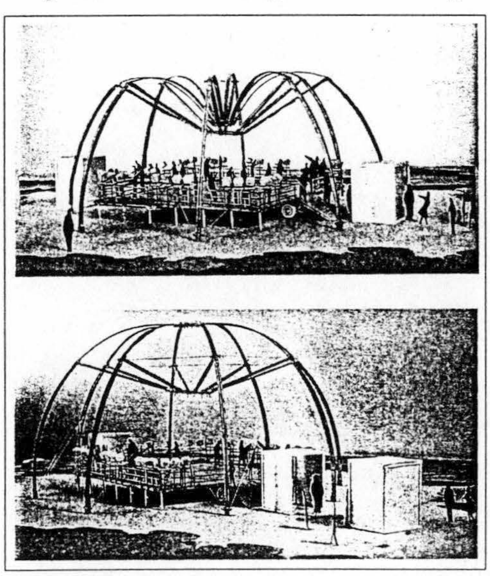


As Renzo Piano states;

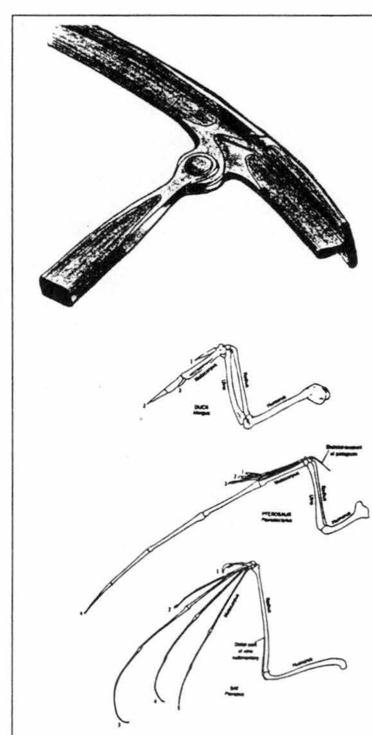
"the tree system is based on a continual refraction of light between leaves creating areas of shadow without impending ventilation. Basically the Houston screens are no more than large leaves geometrically arranged so as to leave passage for air but also to exclude the ultraviolet rays that would damage the works of art." 2.

Gallery screens compared to an ex-ray picture of a digitalis flower. 3.

A final example is the IBM 'Ladybird' travelling Pavilion, an unexecuted project designed by Renzo Piano in 1986. The collapsible structure is derived from an interpretation of the opening and closing structure of bats and birds wings. In an emotive sense the IBM pavilion is fragile, mobile, light and temporal.



Model views of the structure unfolding. 4.



Skeleton wings that inspired
the structure of the folding arches. 5.

Visual inspiration

Our perception of beauty is closely associated with experience, and our experience closely associated with the ever pervasive natural world. The natural environment forms the visual backdrop and provides us with the experience upon which to base aesthetic judgment and understanding. Many aesthetic principles hold true now as they have through history, for example the perception of proportion or the contrasts of colour and texture. Other perceptions of beauty reflect our technological progress, such as our ability to produce smooth and fine grain finishes. The nature of visual information available to us via television and media has presented the designer with an eclectic array of design sources. It may be suggested that this experience has resulted in an increased diversity of design activity and a modern appreciation of the aesthetic of both order and disorder.

There is a seemly endless source of inspiration that is the result of our technological achievement. Some of these principles and observations are regularly used by designers. Many others exist in the domain of technology but are waiting to be sourced by the architect. Whilst some of the issues may appear to have only emotive value they may also have significant technological implication. For example:

The question of what colour to finish a building can be a technological question. Dark colours are renown for soaking up heat, pale colours reflect heat and light. A building can directly benefit from this observation. The choice of a lighter colour in a warmer climate can reduce the amount of energy required to cool a building.
1.

It is recognised that colours located on opposite sides of the colour spectrum emit the highest level of contrast. We can readily identify this phenomena in nature. In experiences such as the observation of a vibrantly coloured setting sky or in the observation of a red flower in a green landscape.

2. Our understanding of contrast and visual distinction as based upon nature may have direct technological implications for design. For example, for reasons of safety or visual identification we may conclude

that the safest colour for a marker at sea is orange, as it is the most visually distinctive colour when placed next to blue. We may decide that the most obvious colour for a cafe in a green park is red, or that the signage on roads should be yellow as it is a particularly vibrant colour when seen in the context of a bitumen road.

Visual inspiration from nature may also have purely emotive reasons behind its regeneration. The architect may simply justify a design response by presenting the emotive value of the original model. For example the changing hues of a chameleon may produce an emotive response in the observer that the designer wishes to imitate. The soft tonings of pink grey and cream bark on a eucalypt may inspire the designer to imitate them for their aesthetic and spiritual qualities.

Our perception of the natural environment, its beauty and the technical knowledge it presents, has altered over time. Our perceptions of nature reflect the fact that whilst we have mastered many aspects of the natural world we now understand and perceive its delicacy. Technological progress has allowed humanity to achieve the exceptional, such as observe the structure of a molecule or watch a string of comets crash into the atmosphere of Jupiter, but for all our knowledge we are still subject to changes in our environment be they catastrophic or gradual, the result of natural variation, or our own meddling.

Inspiration from environmental concepts

To date the discussion has concentrated upon particular elements of nature, which may be observed to produce design responses, based almost directly upon the original design model. Design inspiration may also be drawn from a broader perception of the natural environment. This is an emotive and controversial approach, subject to different interpretation. A personal view will clearly affect the architect's design reaction to environmental concepts. Ideas derived from the environment may include an observation related to its interconnectedness, ephemeral quality, structural economy, evolutionary development, chaotic characteristic, adaptable quality, frugality or diversity.

The architect may be motivated by an intellectual understanding of the natural environment and also by personal values. Exposure to new scientific data or the discovery of practical knowledge concerning the natural world may stimulate design thought. Personal credence and emotive stimulation such as the gut feeling that our relationship to the environment needs to change are other stimulative options. Both the economic and emotive costs of environmental destruction may lead the designer to look towards nature for regenerative models applicable to sustainable and sensitive building design. As Frei Otto states;

"If one seeks in the future to make the increasingly built up environments more humanly equitable and with due regards for ecological interests, then an understanding of those processes which produce natural structures is an indispensable precondition. Knowledge of these processes enables architects to find constructive solutions, which permit integration with Nature." (F.Otto) 1.

It may be suggested that natural forms have an emphatic relationship to their environment. Each element being part of a greater whole. Such an observation may be the basis of a design response. The architect may choose to reinterpret the intimate relationships and delicate balances that exist between the component parts and the whole, responding to this observation in a built sense. An understanding of the holistic make-up of the environment may lead a designer to consider the impacts of their own designs within a much broader environmental context, such as the relationship of their building to not only the local, but the regional and global natural environment. In a cultural sense the designer may take the holistic view and examine the relationship of their architectural responses in comparison to an Australian identity or history of built form.

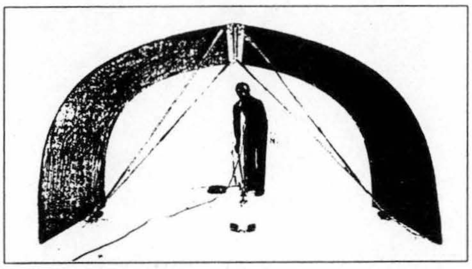
It may also be observed that many natural structures have a fragile make up and an ephemeral life. They may be viewed as transitory objects their existence filling in only a short segment of the regenerative cycle of life. This may be viewed as another natural pattern that may be reinterpreted into an environmentally sensitive building pattern and likewise into a built technology. The ephemeral existence of some things in nature indicate economic possibilities. For example it makes sense to build a structure to last only its necessary life span.

A natural and a handmade example between which many comparisons may be drawn upon environmental grounds. (Birds nest and a New Guinea women's tree house. 2.)

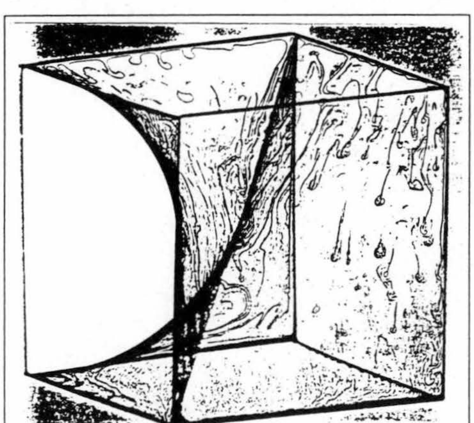
The ephemeral existence of life may be viewed as one of nature's appealing and emotive qualities. For example a butterfly survives in its winged state for only fourteen days. A part of the emotive beauty of this creature is its transitory life. An architectural interpretation of the way a butterfly exists within the global view may possibly result in a more desirable response to building on a fragile planet, one already heavily scarred by human intervention and disruption.

The temporal qualities of nature and building may not necessarily relate to the weight of a structure. Some buildings and some natural structures may be of a significant weight, yet still be very delicate intrusions in the landscape. Take for example the traditional home of the Eskimo (the igloo. 3.) The igloo is a temporary building yet it is not a light structure. In the case of both the butterfly and igloo the entire quantity of ingredients used to form the structure are directly returned to the biocycle. Both examples do not irretrievably withdraw or lock away any materials from a balanced natural ecosystem. This may be another inspiring and emotive view of the world with the ability to feed a technological response.

One of the beautiful and tantalising aspects of nature is its perceived frugality and interconnectedness. Translating this quality into architecture is a frequently explored path, the intention being to reduce the level of elaboration in design and create a building that sits comfortably within the finely balanced network of nature. In the area of structural economy there is a profound source of knowledge to be discovered. The interpretation of nature in this way may be relevant to those who seek a reduction in the level of material consumption in architectural design.



As an example consider Renzo Piano's minimum shelter, pictured aside 4. This structure is based, in the emotive sense, upon nature. The design searches for the highest level of economy in material use and structural design. This is frequently found in nature. The shelter uses a single sheet of plywood for a roof and wall element that is tensioned into both a structure and a skin. The two elements are held together at the ridge by a hinge and its shape is created by tightening the cables. The shelter, like structures found in nature, is synonymous with the structural forces held within it. This design does not exaggerate, if anything less was done the structure would fail. Renzo Piano states that his minimum shelter, like a natural structure, has a particularly high strength to weight ratio, and does not have components that do not play an essential role in its performance. 5. The building reflects in technological form an emotive quality of nature, where every component is interdependent.



The interdependence of structural form may result in a significantly more efficient building. To create such a building requires a much closer consideration of structural forces. In Piano's structure, as in nature, the members work with other members, dispersing loads that would be too great for any single element to carry unless appropriately designed.

Further on the topic of architectural frugality and design extravagance, Frei Otto presents the following question; "What does architecture look like when it does not exaggerate, when it does no more than necessary, when no longer individuals erect their monuments on an ever scarcer earths surface at the expense of others..." 6.

In the search for an answer to this fundamental and emotive question Frei Otto has looked towards nature and has discovered many natural systems that do not exaggerate and may be applied to building.

7. Soap bubble within a frame and a minimal surface tent, Texas A&M University 1967.

All these regenerative observations are highly relevant concepts applicable to technological design. For every generation there are certain challenges. For example in the 1900's it was the social dislocation caused by the industrial revolution. For our generation it is our excessive consumption and the unsustainability of our lifestyles. The designs of Frei Otto and Renzo Piano take on this challenge and attempt to present a sustainable ideal. This approach establishes a secure association between nature and design

Another inspirational source is the adaptability of many natural forms. For example plants and some animals have the ability to physically change their form in response to changes in their environment. For example the North American brown bear has the ability to lower its heart rate and hibernate for a significant period of the year to avoid starvation. Many plants have the ability to change the shape and chlorophyll content of their leaves in response to different lighting conditions. This type of adaptability may inspire design. For example a building may be designed with an in built flexibility so that it may be adaptable to numerous functions over time. A house may be designed to grow and shrink with the changing needs of the family, or the changing thermal requirements of the seasons. Evolutionary adaption and the opportunistic behaviour of nature may be viewed as an inspirational quality directly applicable to architectural design. Every site presents the designer with a different set of environmental conditions. The architect may look for the most favourable niche within the site that fulfils their habitation requirements. A lizard or a marsupial would do exactly the same. A plant in its habitation of an area will thrive in those locations that most suit its life needs, on the outskirts it will struggle and at times appear slightly different from its standard form as a response to the unfavourable conditions. In architecture a building may also alter in relation to different environmental conditions. In Queensland it may not be necessary to use glass in a window frame yet in Victoria or even further south in Tasmania this is not an option and one may even need to use double glazing to create a habitable space. Using glass or not using glass may be viewed as a simple adaption of built form. This is not unlike the thicker coat a marsupial will carry in cooler regions in comparison to those inhabiting warmer regions. The site responsive solution may be viewed as the adapted condition in built form.

Chaotic characteristics and the inexplicable patterns of disorder as seen in nature has stimulated a great deal of scientific thought and design thinking. One example is Bernard Tchumi's walkway in Park la Villette, where alternate rhythms are overlaid to create disorder in the way the two patterns collide. This design response can be closely associated with 'chaos theories'.

The natural environment is an inexhaustible source of inspiration for the architect. As discussed, ideas may come from the smallest of details, or may embrace the largest of concepts. The use of nature as a design source will reflect intimately the architects personal opinions and sensitivity to the environment. A regenerative approach that looks towards nature has the potential to shape society's attitude towards the natural environment. Our technical understanding of the environment is forever increasing and our emotive responses changing, this opens new opportunities to interpret and reapply such knowledge to architectural design.

Inspiration from artifact

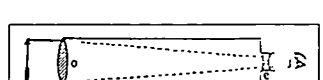
Deriving ideas from artifact

Artifacts surround us in our waking lives with their images pervading our dreams. They are more than just the physical results of our labours, essentially reflecting our imagination and strivings. They fulfil our physical needs and provide spiritual sustenance. The artifact is imbued with symbolic and iconic reference in our culture. The simplest and dullest of artifacts may be as much a source of inspiration as the most fantastic and unique products. Ours is a consumer society saturated with crowds of objects which compete for our attention. This unstopping torrent of images and products serves to make them incomprehensible, and they can come to seem meaningless in their banality. By not accepting these artifacts as common or dull the designer may draw from their embracing philosophies, prejudices, causes and contradictions.

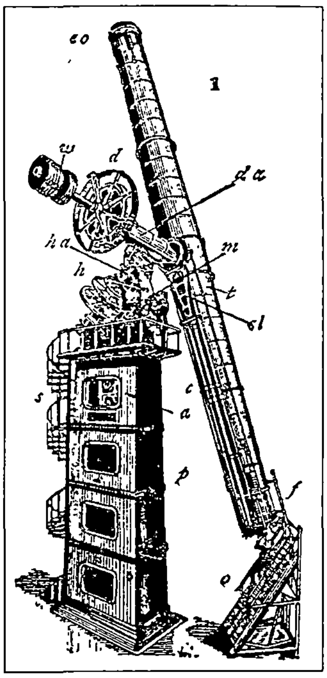
It is easy to believe, as we are swamped in the tremendous flood of images and artifacts, that random processes dominate our progress. However, the vast majority of artifacts express a common order that is a result of society's needs and demands. They reflect our beliefs and reveal something about the underlying social reality. This understanding may be of a rational nature involving structural or economic knowledge. It may reflect a scientific knowledge of materials and processes or involve forecasts of demand and choice. Equally our understanding may be of an intuitive nature, with emotive conditions involved. Ancient mythologies are still incorporated within many artifacts and rituals and as society changes new relationships and narratives are formed.

Ideas may be viewed as a product of the human mind and as such may be thought about and tested. Artifacts however enter the mind only through our perception, thus they may be rarely ever truly understood. We can always propose further questions about the object, or by meditation and thought change and enhance our own understanding of it. It is crucial that the designer is able to maintain a high level of curiosity when observing the artifacts and processes that characterise our society This approach may lead to a greater understanding of the artifacts around us. The questions that may be asked about artifacts cross the disciplines that have been built up around our ideas: art, religion, philosophy, history, science and engineering, to name a few. By not limiting ourselves to a particular discipline in a search for inspiration we may increase our chances of being innovative. It is hard to predict where a design process may take us. Design development may be in a direction similar to our existing design intentions or it may be in a totally new direction, resulting in a single design decision or inspiring a plethora of new ideas. In this random fashion design feeds upon itself, requiring at times only its own history and input to incite and stimulate the process. The process may be viewed as a self perpetuating one where ideas are extended and applied to alternative areas with advances and design failures extending and stimulating further thought and design activity.

Successful and creative solutions are often the result of the modification or the adaption of existing artifacts to a new application. The creator may examine an object already in existence, and see how it may be adapted to another need. Consider for example the invention of the glass lens. This piece of design technology has been adapted to a multitude of uses, such as the telescope, microscope, periscope, camera, glass spectacle and so on.



Galilean telescope 1.



Technological discoveries may influence humanity for an extensive period of time as the potential applications are explored and the impact of the discovery realised.

It has often been suggested that the invention of the glass lens ignited the modern day scientific revolution. Galileo's telescope was the first technological discovery to present a different view to the teachings of the church. It proved that the Earth was not the centre of the universe as the religious leaders had fiercely taught. The discovery opened may doors of investigation having a profound affect across the board. These observations lead to innumerable design applications

2.

The Wright brothers achievement of flight may be viewed in the same light. Orville and Wilbur Wright did not invent the concept of flight but observed other designers' attempts and modified existing models to create a successful flying machine. The Wright brothers added to the design equation their knowledge of bicycle technology and kite flying. The related fields of design knowledge were intermeshed to create an effective design mix.

As another example consider the early developmental history of the internal combustion engine. Leonardo da Vinci developed his ideas for a mechanical engine from the observation of a cannon. He modified and adapted the existing principle, by putting a piston into the shaft instead of a ball. Unfortunately the machine did not work, but the idea was a step in the right direction. In the following centuries many inventors tried to make Leonardo da Vinci's idea work. None had much success until late in the 19th century when the first practical engines were developed. Of particular note were developments by the German inventor Rudolf Diesel who thought of replacing the gunpowder with petroleum distillates. This type of adaptive and developmental thought is common in the area of artifact inspired design response. The current or past ideas are reassessed and extended by different people under different design criteria and contextual conditions.

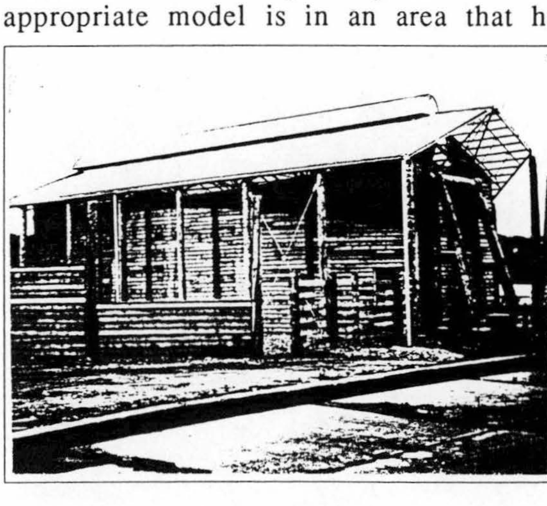
Some of the greatest advances in the last two hundred years have been in production and product technologies. Whilst many of our basic needs for shelter and warmth have stayed the same, huge advances have been made in material technologies and construction techniques. Knowledge of new developments may inspire the designer on to further creative thought processes. Technology may be viewed as the master key to the doors of design innovation.

In the area of constructional process many ways of fabricating structures may be transferable in design. For example ship building techniques, space satellite construction, caravan or mobile home prefabrication, are examples that may present the architect with constructional process applicable to architectural design. Alternatively the ability to predict how a structure will interact with the environment may also be important. Improvements in thermal imaging may allow better mapping of heat loss and result in more thermally efficient buildings. Specific knowledge of the sound absorption properties of particular products may solve noise problems. In a bid to reduce the risk from earthquakes a designer may wish to study the latest oil rig structural technologies. There are many sources of information on the manner in which a structure withstands weathering, from the latest in paint and finishing technologies to studies of traditional building methods. In antithesis the designer may wish to achieve a weathered look for emotive reasons and may consult artistic sources for techniques that are applicable.

A design brief may contain strict environmental guidelines or there may be altruistic motivation to seek the most environmentally friendly design. There are many factors that may be considered some related to the site, others to the purpose of the structure. The designer may wish to utilise materials from the site, such as an existing structure or raw materials, to save on material and transport costs. Another factor in achieving a sensitive design may be to consider the longevity of the structure and its short or long term impact on the site. The humble freight container is often used as a basic unit for the delivery of services as diverse as refrigeration facilities to desert environments or communication facilities to the Antarctic continent. This solution avoids damaging construction activity in locations where resources may be scarce. The container is easily removed from the site when its purpose is completed and may be recycled or placed in a new location. This concept is similar to that used by nomadic or semi-nomadic tribes who carrying their structures from location to location.

The designer should not ignore the regenerative potential of hands on experimentation with materials, as this may lead on to the discovery of new design possibilities. Within the vast array of materials produced for many specific purposes there are many alternative uses waiting to be discovered and exploited. Some qualities may be less obvious to those who regularly deal with a material yet outstanding and highly applicable to those who experience the product from a different point of view for a first time. Many products are devised for specific markets such as the aviation industry, automotive industry or leisure industries, with some thought these products be transferable to architectural applications.

Where we look for reusable technologies is dependent upon the design goals and upon any constraints that may apply to the project. The architect may use the design goals or limitations to identify comparative models. For example, if there are certain material limitation the architect may look towards other models that experience the same constraints. If the architect is restrained by the use of timber there may be a decision to look towards yacht design, furniture design or possibly musical instruments for design inspiration. Often the best place to discover an appropriate model is in an area that has had a strong history in the use of the material. The length of time a material has been employed in an industry often equates with the level of technical design knowledge.



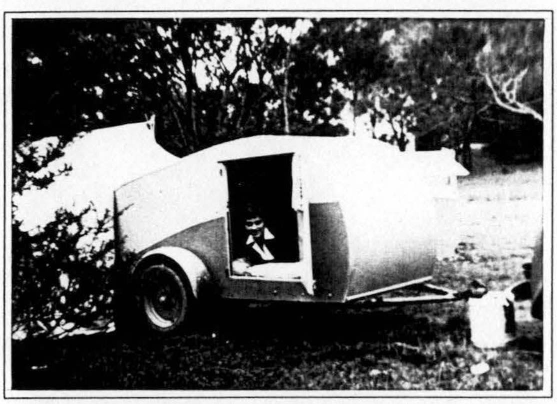
We may find, as in this example, inspiration in timber yacht design. Timber has been used for centuries in the construction of boats. The skill with which it is worked, the processes of construction, and the quality of the final product can only be admired.

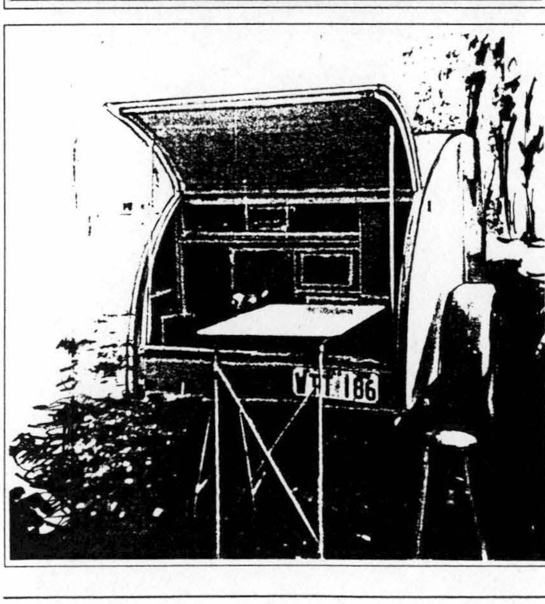
Strahan visitor centre, Tasmania, Robert Morris-Nunn. 3.

The greatest potential for regenerative design may occur when we insert an idea into architecture from an area of design where the knowledge that we have discovered is at a technological pinnacle. This may be the result of tradition or reflect a concentration of effort inspired by economic or political motivations. For example we may characterise the history of the automobile as having been inspired by economic opportunities or consider the political nature of the space race. Many other pressures be they contextual, environmental or social may result in the concentration of design energies on the resolution of a technological object or design aspect. The discovery and reapplication of such an advanced model may significantly boost and improve design thinking along similar lines.

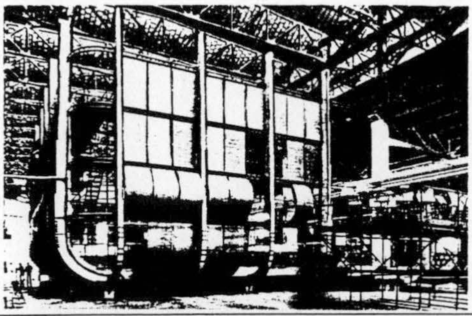
One of the basic concerns of the architect is the manner in which people perceive and utilise space. The considerations may include spatial constraints, optical conditions and emotive qualities. For example the acoustical properties of particular shapes may be determining criteria, or the designer may be confronted by a set of limitive spatial requirements. The brief may limit the size of the building or the size of the rooms within it. This may be for any number of reasons, such as a low budget, environmental concerns or particular site constraints. In this instance the designer may choose to look for a model that has had similar conditions imposed upon it. A design with tight spatial boundaries, such as a submarine, boat, car, train, prison, Japanese home, light house, or spacecraft.

Some regenerative models may prove to be far more fruitful than others. The initial comparison may inspire a chain of other associations and the examination of one idea may lead on to the discovery of another. In this way the model may provide inspiration on a level that the architect was not expecting to find. The unforeseen inspiration may be of technical or emotive value to the progress and design development of the new design response. For example the examination of a caravan for knowledge on clever spatial design may lead to the discovery of an interesting constructional detail, or an aesthetically pleasing form. The interwoven design features of the original allow one regenerative thought to lead to another.



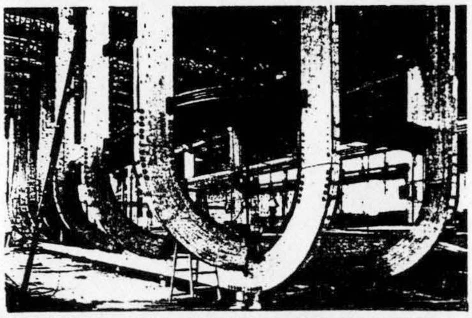


1950's plywood caravan. 4.

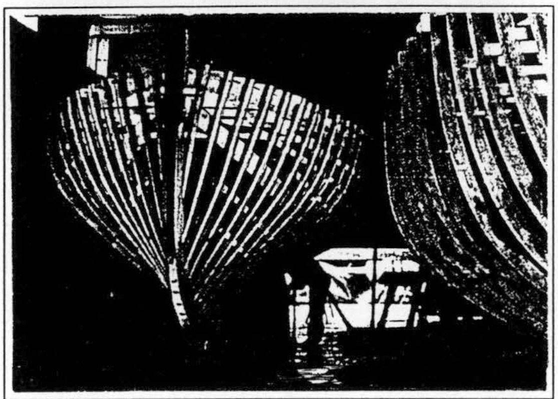


Setting for the Prometeo Opera, Venice and Milan, Renzo Piano (1983-84) 5.

In another case the building's function or purpose may inspire the discovery of a regenerative idea. In this instance the requirement for a performance space has directed the architects thought processes along acoustical parallels.

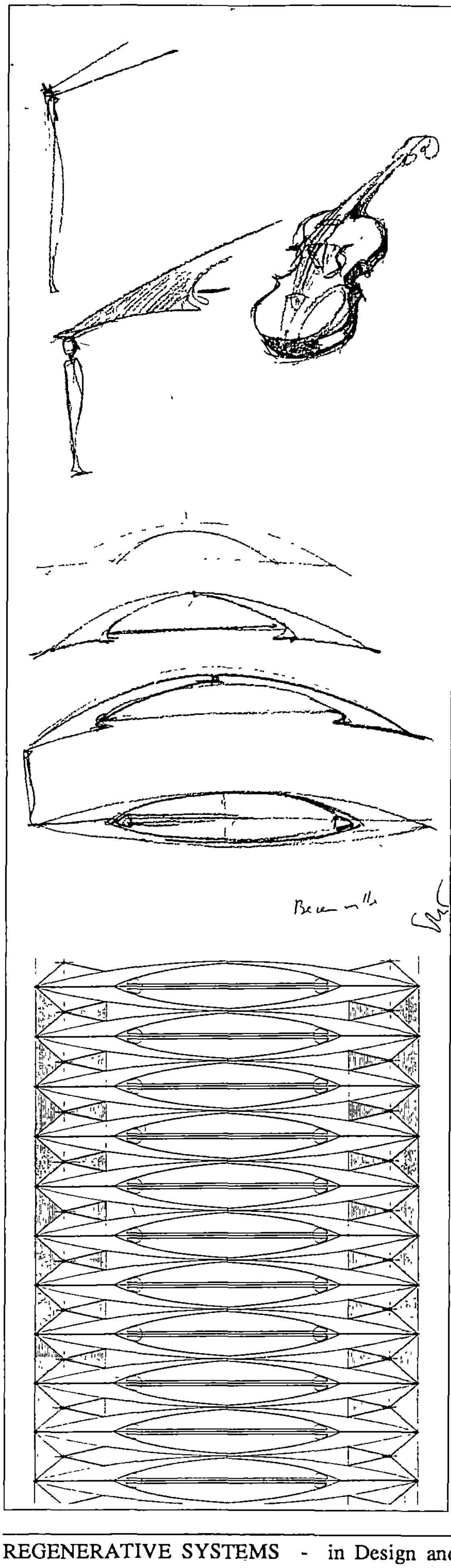


Renzo Piano's setting for the Prometeo opera has uncovered an emotive and technical relationship between instruments, boats and buildings upon acoustical grounds. The result is an intimate relationship between the use of the space and the form of the building.



"Like the skeleton of an animal the structural hull is like the soul of a living thing." (Renzo Piano) 6.

Yachts under construction. 7.



Santiago Calatrava, Burenmatte Suhr Aargau, Switzerland 1984/88. 8.

In the design of this community centre in Switzerland Santiago Calatrava has chosen to seek regenerative inspiration in the aesthetic form and in the structure of a musical instrument. It is chiefly the bow and the plywood body of the violin have inspired the architects design thinking.

In both Renzo Piano's opera setting and Santiago Calatrava's community centre, the regenerative model supplies the constructional knowledge and also substantially enriches the emotive quality of the space. The spectator can clearly appreciate and understand the relevance and the value of the associations as the analogy readily stimulates their own emotive responses.

Access to possible sources of design stimulation has never been easier than at present. This includes historical sources and also ideas from different cultures. Such knowledge and design evidence may provide an aesthetic cue for the designer. For example a piece of ancient Egyptian sculpture, a 1930's teapot, or a car from the 1990's may provide the visual stimulation for a design response. The eclectic array of inspiration at our fingertips through museums, books or television has enormous stimulative potential. Today is like no other time, as one minute we may enjoy the visual experience of a potter throwing a dish, and in the following moment we may experience a commonplace plastic moulded hand basin. Design associations tend to present themselves at every turn in our daily lives. The potential in this uncontrolled and random association of design knowledge is very exciting for those with their creative minds alert.

The architect may find stimulation in the transfer of visual features from one area or one culture to another. This cross-cultural fertilisation and cultural understanding may influence the design agenda as alternative design forms and approaches are tested in alternative contexts. For example an understanding of traditional Japanese architecture has inarguably influenced modern Western design, and Western design has inarguably influenced Japanese architecture and design. As another example consider the effect of the Bauhaus School on design. The modernists had an outstanding global influence as their theories were tested and applied to numerous design circumstances. The individuals involved and their philosophies have cast an enormous shadow over design thinking.

The history of design is the history of people and individual designers. Many different philosophies and ideas have arisen, some to dominate and change cultures others as mere footnotes. The designer may choose to appropriate ideas verbatim, or choose to reinterpret in the light of current context. The continual reuse and reinterpretation of ideas and concepts is characteristic of the design process. If the regenerative process is employed in a conscious manner the opportunity exists for designers to greatly increase the quality and variety of their inspirational sources.

A diagrammatic conclusion

In conclusion, there is an extensive range of ideas that can be reapplied to architectural design. The inspiration for architecture, according to the pattern of the discussion can be found in either nature or artifact. Ideas from these areas may be gathered from structural, functional, economic or aesthetic observations.

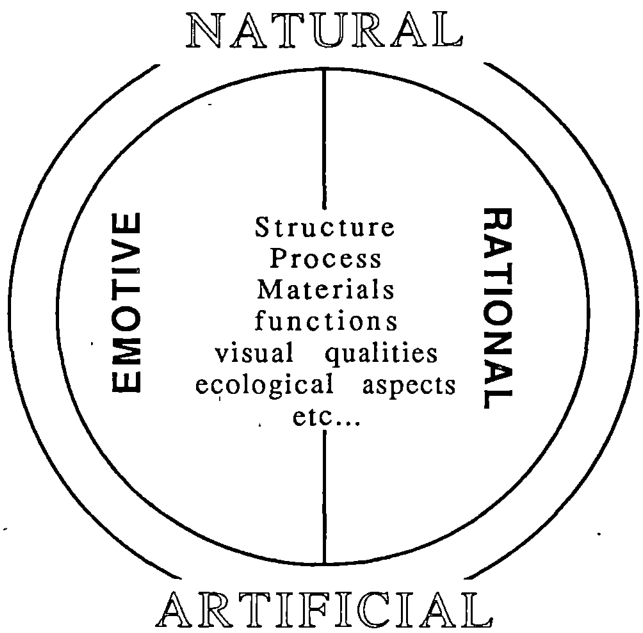
In analysing the sources we have uncovered some quite complex issues that tie emotive and impulsive design inspiration to logical, scientific, rational and technological design implementation. We have discovered that technology may not always have a rational basis to its formulation.

The following diagram is designed to clarify the designer's understanding of the range of regenerative sources.

Before we examine the diagram I shall define the meaning of the terms used within it.

NATURAL	Indicates design sources of natural origin. These sources exist independent of humanity.
ARTIFICIAL	Indicates design sources that are made by human skill and labour, as opposed to natural.
RATIONAL	Indicates the grounds upon which the idea may be found or applied, suggesting a process endowed with the faculty of sound judgment and reason.
EMOTIVE	Indicates the grounds upon which the idea may be found or applied. A process without faculty of reason or logic.
Structure	Relates to the structural framework and form of the entity.
Processes	Identifies the pattern or the sequence of actions that result in the functioning or the creation of the object.
Materials	Refers to the substance or substances from which a source is made or composed.
Functions	Relates to operations that the entity may perform, and the working parts of its structure.
Visual qualities	Identifies the optical qualities of the source.
Ecological aspects	Identifies the features of the design model that are responsive to the environment.

The diagram identifies some of the regenerative sources that may inspire architectural design. It is important to note that it does not represent a definitive list of possibilities but presents a springboard from which to leap.



For example we may find design inspiration in;

a natural structure	- examined upon emotive grounds - examined upon rational grounds
a natural material	- examined upon emotive grounds - examined upon rational grounds

Upon either emotive or rational grounds inspiration may be found in;

a functional aspect of nature
a man made structure
the function or use of a structure
a structural process
a materials performance (function)
the material used in an artifact
visual aspect of nature
etc....

a natural process
the structure of an artifact
a structural material
a material production process
the function of an artifact
the process behind the creation of an artifact
a visual aspect of an artificial object

As demonstrated the designer may extract numerous provocative paths of design investigation from this diagram. The possibilities are only limited by the observer's imagination. Further headings may be added to the core of the diagram and those topics examined under the thought processes and comparative options suggested. Because the possibilities are virtually endless there soon forms an imperative for closure towards a solution. To achieve this decision making process intervene relating the course of association to the design objectives and parameters of the project.

Section C:
Finding the 'primary generator'

This section discusses a number of techniques and methods and the creative path by which regenerative ideas may be uncovered. The intention is to support the discovery and application of the regenerative process. The segment includes dialogue on creative decisions, asking questions, unexpected discoveries, searching our memory, ideas through play and practice at idea generation. A clearer understanding of these topics as related to regenerative systems may aid in the sourcing of design inspiration. Following this segment, association, analogy and metaphor will be discussed, with the motive of identifying these processes as design tools by which regenerative ideas may be discovered. Under the heading of 'the practical application of an idea', the factors that may hamper a regenerative process are analysed, as are the issues that may prevent the free exchange of technologies and affect the realisation of a regenerative idea into built form. The benefits of using models, material contact, tool technology and the way these techniques inspire and affect the development of a regenerative idea are assessed. Finally, the way these factors act as a gauge, determining what is technically and physically possible to create in a regenerative sense, is reviewed.

Some techniques and methods

Creative decisions

All ideas are worthy of examination. Many of humanity's most significant technological ideas were, at their time, considered outlandish, such as landing on the moon, developing interactive computers, microwave technology, constructing the Eiffel Tower and even the application of electric light. These ideas and many like them have marched onwards, to the embarrassment of those who prejudged their potential.

"with regard to the electric light, much has been said for and against it, but I think I may say without contradiction that when the Paris exhibition closes, electric light will close with it, and no more will be heard of it."
(Professor Erasmus Wilson, Oxford University, 1878) 1.

To prejudge an idea is to sever its regenerative potential. If the intellect and the rational mind judges an idea too early we may forego the opportunity to find a later regenerative association. Friedrich Schiller the German philosopher wrote the following letter to a friend who believed he had lost his ability to think up good ideas:

"The reason for your complaint lies, it seems to me, in the constraint which your intellect imposes upon your imagination. Here I will make an observation and illustrate it by an allegory. Apparently it is not good - and indeed it hinders the creative work of the mind - if the intellect examines too closely the ideas already pouring in, as it were, at the gates.

Regard in isolation, an idea may be quite insignificant and venturesome in the extreme; but it may acquire importance from an idea which follows it. Perhaps, in a certain collocation with other ideas which may seem equally absurd, it may be capable of furnishing a serviceable link. The intellect cannot judge all these ideas unless it can retain them until it has considered them in connection with these other ideas." 2.

In the regenerative process it is necessary to delay judgment. This may be done by objectively filling the mind with information, observations that may in the future find a comparative partner, or potential regenerative application. The designer may ask the imagination what else?. As frequently the more observations that are made, the more likely it is that a good solution to the problem may be found.

"New creative ideas are usually combinations of existing ideas. The more existing ideas you have in you head, the more connections you will be able to make and thus the more creative you will be able to be." (K.Hanks & J.A.Parry) 3.

In the regenerative equation quantity may build quality. Often the longer the designer can delay the judgment of ideas, the more alternatives there will be to chose from. As all designers know the first ideas are not always the best ones. An architect may need to explore further instead of taking the first option at hand.

Friedrich Schiller in his letter also suggested that it is important to give ourselves a chance to digest ideas. Regenerative ideas need time and care to allow them to mature and resolve their flaws and weaknesses. It may be to our own detriment to judge them at the gates of their entry into our intellect. Regenerative options may be fruitlessly reduced by prejudging an idea before it has been thoroughly examined in the light of its regenerative potential.

To discover regenerative ideas it is necessary to question the design problem. We may need to approach the task with an open mind. We require to test, experiment, feel, and not assume. Watch a small child examine a new toy. The child will test the item in every possible way. The toy will be shaken, turned upside down, and put in the mouth. The child will carry out a complete comprehensive sensory examination. When done the child will know much more about the toy than an adult will. An adult is likely to limit their sensory examination of the object, afraid of embarrassment. They will assume and prejudge matters and will be less willing to make mistakes to gain a better view. In comparison a child lacks self cognizance and has an intense desire to learn. A child will thoroughly examine the objects it encounters without limiting preconceptions as to how this should be done. This readiness to explore is essential in the search for the primary generator.

A child using dominoes as building blocks. 4.

As Charles Steinmetz stated;
"There are no foolish questions, and no man becomes a fool until he has stopped asking questions." 5.

(Charles Steinmetz was one of the worlds foremost electrical engineers. He worked on alternating current systems and devising and calculating methods that enabled engineers to design more efficient electrical machinery. He lived 1865 -1923).

The effective designer needs to not only be an effective gatherer of ideas but also a good decision maker. An increase in design options may benefit the designer, but the ability to be able to sort through the options and make a final decision is essential. In the regenerative approach there invariably comes a time when a sufficient number of ideas has been collected and a critical analysis can begin. Frequently the architect may be intimidated by the threat of too many options. To improve the ability to make good decisions, the designer needs to be exposed regularly to the task of making them. Confidence in making decisions is attained through experience. This experience is supported, not only by successful results, but also by failed choices. Decisions may be based upon either logic, intuition or both. In even the most basic process of design a phenomenal number of conscious decisions are made.

Asking questions

In a regenerative process it is vital to ask questions, as finding the right answer to a problem may be as simple as proposing the right question. It is clear that reason can at times readily answer questions, but our imagination needs to ask them. In the search for regenerative ideas it pays to pursue all possible parallels. By constructing and proposing deliberate questions we may consciously direct the creative mind along the path of regenerative thinking. When seeking design ideas the designer may ask questions such as; 'What is this like?' ... 'What does it suggest?'... 'Is there a parallel?'... 'What can be adapted?' and 'Is there something to copy?'. Questions like these may bring to the surface comparative models that are applicable to the problem at hand.

The question of 'is there something to copy?' may sound like an act of plagiarism but there is no offence in taking a lead from someone else's thinking, as long as the activity does not legally or morally damage the creator. We shall further discuss this in the section titled 'the ownership of ideas'. It needs to be acknowledge that without the borrowed or the adapted copy there would be very few inventive ideas at all. Designers and creative people, however famous, are all to some extent borrowers. For example, Shakespeare used a Danish legend and shaped it into 'Hamlet'. He moulded what was a relatively dull legend into a brilliant drama. Le Corbusier borrowed the form of a nun's hat to use as a roof in his church at Ronchamp. The result is a building of global significance. Some open recommendations, on the debatable subject of plagiarism, are made in the following passage.

"Make it a habit to keep on the lookout for novel and interesting ideas that others have used successfully. Your idea needs to be original only in its adaption to the problem you are working on." (Thomas.A.Edison) 1.

Additional questions to ask in a regenerative process may be 'What can I make this look, or feel like?. Or 'What can I incorporate?'. Fashion designers regularly asks such questions. Many clothing designs have been based upon other objects. For example swim wear has been modelled upon corsets and old fashion brassier styles, women's coats have been based on military attire and elaborate evening dresses on birds or delicate flowers. In architecture, buildings have contained strong reference to steam liners, such as the Villa Savoy by Le Corbusier. Houses have been made to feel like tents, such as in the 'tent house' in Queensland by Gabriel Poole. Or yacht fixtures and fitting have been used to construct buildings, such as at Yulara Tourist Village, designed by Phillip Cox and partners.

Another constructive question to ask may be 'what other power or energy source could be used?'. Take for example the sewing machine. This device has been improved upon along a path that has involved the technological remodification and alteration of the energy source, used to power the machine. Firstly there were the hand operated sewing machines. These were succeeded by the levered or foot powered machines, followed by electrical devices. If we extend these thoughts, a future improvement may involve the development of an independently powered solar sewing machine.

Questions that relate to the modification of an object or to the modification of a process may lead to an enormous range of new design possibilities. We may ask, 'How can this be changed or altered for the better?'. Many of today's building products have benefited from this question as fine adjustments are made to the product to make them easier to use, more visually attractive, thermally efficient or weather resistant. The socially relevant question of 'How can I make this product more environmentally sound?' has lead to numerous developments and changes in the design and construction industries.

In the search for ideas we may ask 'what may be combined into one element?'. For example the modern shirt has the collar and cuffs attached, in previous times these were separate elements of dress. A comparative architectural example is wire mesh glass. This product combines a security barrier and a safety device with glass. Another example is the gang nail plate which combines a metal plate and nails into one element, or the self tapping screw with a tip shaped like a drill and a thread designed to grip the timber.

When searching for a design solution we may ask 'what can be added to make it stronger?' or 'what can be removed to make it lighter and more efficient?'. We may ask 'what if it were smaller?' or 'what can be eliminated?'. The question of what can be eliminated is of foremost concern in the genetic development of food stuffs. Food engineers look for ways to reduce the objectionable such as pips in grapes and the bitterness in cucumbers. Annihilating the objectionable is also a question that is relevant to architectural pursuits. The desire to eliminate smells rising from drains resulted in the development of the 's' bend. In another case the question of 'how can we make the process faster?' may have inspired the development of paint sprays.

There are many questions that relate to the rearrangement of an existing order, such as those that look at changing the sequence or reversing the elements in design. Reversing an aspect may result in a new solution. For example a question like 'Could the design be reversed?', may lead to a decision to place a motor in the rear of a vehicle rather than in the front. The designer may ask questions that relate directly to the inversion of an object, such as should a propeller push or should it pull?. A propeller on a yacht's motor pushes forward but a propeller on a helicopter pulls up. We can likewise rearrange existing models in architecture. We may ask, 'What other floor plan will work?', 'How else can we enter this room?' or 'How else can light enter the space?.' There are innumerable questions that relate to the rearrangement, reversal or inversion of spaces in design.

By proposing questions during the design process, the architect may simulate their creative mind and increase their ability to discover new ideas and possible regenerative associations. The answers to these questions or the thoughts that may be stimulated by them can lead to the discovery of an appropriate regenerative model.

Unexpected discoveries

Many discoveries are not what we would predict. This is the nature of any experimental process. The aim and the method may be preset, but the result are not so predictable. Often great discoveries occur in areas that have already been considered by many others. This is because a major part of the battle is understanding and interpreting the outcomes. Many great discoveries have been the result of experiments gone wrong or the result of the experimenter suddenly gaining some deeper insight. A key ingredient is the willingness to expect the unexpected, or perhaps to see things in a different light.

For example when William H. Mason was trying to create a new form of porous insulation out of exploded wood fibre he created by accident a new building product. During the period that Mason was carrying out tests on the wood fibre in a press, he was distracted and went to lunch, forgetting to turn the pressure off. On his return he was surprised to find that the machine was still running. When he inspected it he discovered that he had created a hard dense smooth board. By accident Mason had created the first piece of 'hardboard', or as it was to be called 'Masonite Presswood'. This instance suggests that a new idea may be just one step away from what we are dealing with. By simply altering a factor in an existing equation, be it by intention or mistake, we may discover a new result. In William Mason's experiments the factor was time. When it was increased he discovered a reconstituted material, and one that took the building industry by storm especially during the 1950's and 60's.

Numerous pharmaceutical discoveries have been made by accident. Such as when a chemical is mistakenly mixed with another or when an unanticipated variable affects the experiment. For example, in 1879 Constantine Fahlberg was working with a new combination of chemicals in his laboratory. Before washing his hands he rubbed an itching lip and discovered that the chemicals he was mixing had a sweet taste. The substance discovered by Fahlberg was developed into a dietary substitute for sugar, known to us as saccharin. Luck may provide the lead, as in Fahlberg's case, but a lead needs to be followed though before it will be of any value to society. This may requires the correct combination of technology and demand.

In hindsight many advances seem characteristic of their time, however complex the discovery appears. Contextual factors tend to play a large role. For example Wilbur and Orville Wright enjoyed flying kites and owned a bicycle business but they had no thought of building aeroplanes until one day they read about a German who killed himself jumping from a cliff with giant wings fastened to his arms and a tail to his back. The Wright brothers were inspired to embark upon the task of creating a flying machine by a combination of contextual factors and coincidental leads. This included their personal interests, technical knowledge and a catalytic reading of an article about a German inventor.

Solutions to problems may be found where we do not expect to find them. Often when searching in a particular place for an idea the designer may find the answer to another concern. For example, Sir Alexander Fleming was carrying out an experiment in a petri dish with bacteria when mould contaminated the dish. Instead of discarding the experiment, as many chemists before him had done, Fleming decided to question the results. On closer examination he noticed that the bacteria exposed to the mould had died, and that the mould appeared to be preventing any further spread of the bacteria. This astute observation and willingness to explore the potential of a failed test lead to the discovery of penicillin. The case suggests that it is important to treat our errors with as much interest as our successes. It is essential to follow the paths that present themselves and see where they may take us.

In another unplanned creative event, Charles Goodyear discovered how to vulcanise rubber. He intuitively new that there must be a way to make something useful out of the rubber compound. He was frustrated by the fact that the substance changed consistency so radically. On hot days it was soft and sticky and on cold days it turned hard and brittle. One day while working with the material he spilt the compound on to a stove. In doing so he discovered the process of vulcanisation. A vulcanised rubber compound can retain a consistency that is relatively constant in either hot or cold conditions. Because of Goodyear's discovery rubber can now be formed into many useful products.

The previous examples are all very technical. It is important to realise that the emotive condition may experience the same effects. For example, a colour may create an unexpected quality. This quality may lead the designer on to further exploration of the phenomena. A landscape architect may discover a certain effect in the creation of a design, as organic elements do not always preform as expected. These aspects may have been inconceivable in the drawing phase of the project. Many installation artists rely heavily on the unexpected effects of their work. The installation artist tends to deal with such issues as they arise, viewing them as assets of artistic potential.

The design process is infrequently a trail of logic, not everything can be predicted so adjustments are invariably made as work progresses. The process may shift from the logical stream to the irrational one or the reverse. Cause and effect play a crucial role in the development of ideas. The designer needs to be able to reassess work as it progresses and thus improve judgment. Some scientists believe that consciousness is not a single unity, but assembled different neuronal processes. The study of the effects of brain injuries indicates that the mind has a belief system and a perceptual system. 1. Problems may be associated with the minds belief system, not its perceptual system. "The mind needs a theory of the world in order to make sense of the constant stream of sensory inputs. But the theory-making part of the brain must also be able to ignore inputs that don't fit within its world view, lest every mistaken perception shake us to our roots." 2. When too much conflicting data accumulates the perceptive side overcomes the brains defence mechanism and forces it to restructure its world view to fit the new information. When the brain is free to pursue a strategy of denial and confabulation there is no limit to the delusion. An awareness of this conflict within our own though processes is essential, as the unexpected can often be ignored for its lack of conformity to the existing view of the world. If this perceptive hurdle is surpassed the designer may discover many things about the aesthetic world.

Not many solutions are the result of forecast conclusion. Advancements may be made in incremental steps or luck may bring along that huge leap. We may find exciting ideas when we are not on the hunt for anything special or when looking at another problem. The unanticipated idea has the potential to lead on to significant creative undertakings. To be able to use an accident or an inconsistency in one's favour and recognise its worth requires a prepared and creatively astute mind. As Louis Pasteur said; "Success favours the prepared mind." 3.

Searching our memory

"Synthesis is the opposite of analysis; and yet, the better we analyse at first, the better we can synthesise later - the more intelligently we have picked our problems to pieces, the more likely we are to find the pieces that will combine into the ideas that can lead to solutions." (A.Osborne) 1.

Memory is a prodigious source of information for artistic judgment. The mind may be viewed as a thesaurus from which the designer may draw design ideas. A way to seek an idea may be to consciously track through the memory for an appropriate model that compares to the design problem. The more information gathered and stored in this symbolic catalogue the more connections the designer will be able to make.

Creation isn't making something out of nothing, it involves organising existing elements into new and different wholes to produce the desired result. Think of this view in terms of the creation of new life. In an analogous biological sense a sperm comes from one source and an egg from another. When we combine the two, the result is far greater and more important than either part. As Koestler states;

"Creativity ... consists in combining previously unrelated mental structures in such a way that you get more out of the emergent whole than you have put in." 2.

A great deal of knowledge has been discovered by such a process. For example, the motions of the tides were known to man from time immemorial, so were the recurrent motions of the moon. The idea to connect the two systems and associate the movements of the seas with the movements of the moon was not accomplished until the seventeenth century. Johannes Kepler a German astronomer was the first to recognise and proclaim that the tides were due to the attraction of the moon. By linking and comparing two known systems Kepler discovered a much larger concept and opened up a vista of modern science and astronomy.

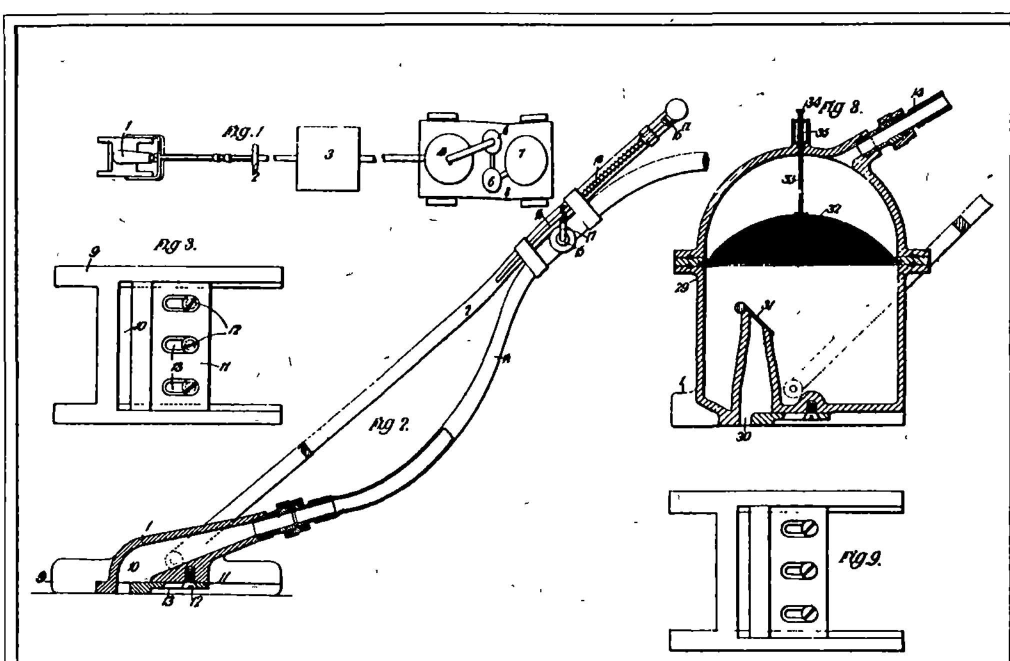
Ideas often bounce off other ideas, and from one mind to another, until they finally strike the right creative nerve and find application. Many great discoveries have been made when the right information bounces in the right direction to the right person. For example Thomas Malthus's economic theories bounced around intellectual circles for many years until they coincided with the mind of Charles Darwin, and helped him develop his theory of evolution. In what is possibly a less significant discovery, but a comparable process, Bill Bowerman devised a totally new type of shoe when the right idea struck his imagination. Whilst eating a waffle for breakfast like thousands of people had before him Bowerman made what was an unlikely association. He thought of transferring this waffle pattern to the bottom of a shoe where it would cushion the foot and provide traction. From this type of collision of ideas evolved generations of high-tech sport shoes and comfortable footwear.

It is often difficult to ascertain whether we are inventing or simply recalling an idea from our memory. Every day we are exposed to innumerable experiences. We tend to remember only a fraction of these experiences, and even less of them in their entirety. Often what remains in the memory is an edited version of the experience, or a snippet of information with no particular referencing point. In design, our memory may fail or fool us, we may think that we have developed an idea ourselves but it may simply be a recalled experience, the reference long lost in the bulk of information stored in our memory. For example the architect may recall a form associated with a long forgotten experience, or a composer may recall a tune that has been heard in passing, without a memory of its source.

Often the regenerative idea will surface via our intuition. Intuition is a part of the subconscious workings of the mind, it is feeling an idea will work even though there is little evidence to suggest that it will do so. The ideas that are delivered to us via our intuition are as valid as those

achieved by reason. As Buckminster Fuller states:
"I call intuition cosmic fishing, you feel a nibble, then you have got to hook the fish." 3.
Many do not bother to check the results of such a 'nibble' or pursue the validity of their hunches in relation to a design problem. This is a grave mistake as both types of thought processes are a part of a well balanced design response. After the realisation of an intuitive thought the idea may be developed at a knowing level, where our consciousness tend to manipulate and reform the idea in the light of our more tangible experiences. The subconscious and conscious are states of experience. One is easy to verbalise the other is not. It may be suggested that creative thinking occurs when both are in competitive balance, passionately competing for the control of our behaviour and therefore design thinking.

In some cases the designer may find that someone else has found the seed of an idea, but failed to develop it and make it grow. Our view of its potential and possible application may be very different from that of the original designer. We may see greater value in the idea, and options that the inventor may not have realised. For example, someone else invented the concept of the mechanical floor cleaner before Hubert Booth did. The device was exhibited at the London Music Hall in 1901. The invention cleaned floors by blowing dust ahead of its path. After the exhibition Hubert Booth approached the designer and suggested that a cleaning device that sucked instead of blew may be far more effective. The designer refused to listen so, Hubert Booth took the basis of the idea and devised his own version, one significantly more successful.



One of the sheets of drawings from H.C. Booths vacuum cleaner patent. 4.

Our memory is a precious resource of immense value to the designer. Many scientific mysteries may shroud its active performance, yet its ability to supply us with inspiration is unabatable. The memory is the designers inventory in which innumerable references may be stored. The active process of sifting through our thoughts, experiences and emotions has much to offer the regenerative process.

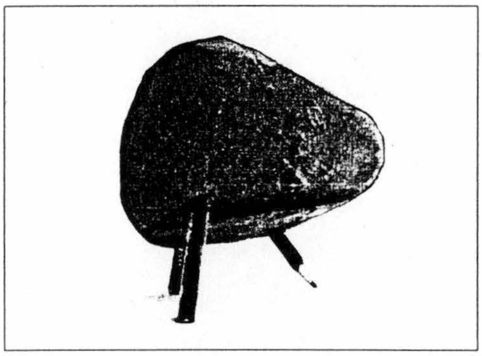
Ideas through play

Play is one of the means by which designers develop creative ideas. In play we often amuse ourselves by testing our imagination, we explore untrodden paths and place very little judgment upon our activities. Play is the testing ground and the media by which humanity explores current artistic and scientific thought. It has proven itself to be an initiating force behind many major discoveries.

There are numerous toys and games designed for amusement that have at a later time been developed into significant and highly relevant technologies. For example the Chinese first invented fireworks, rockets and crackers as toys for their children. The gunpowder used to propel and explode the devices has strongly impacted upon our technological development.

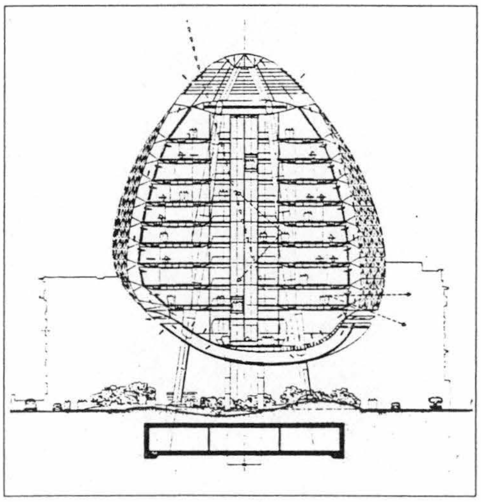
In the same light, consider the development of steam as an energy source. Steam was first employed not to power a mechanical tool or engine but to spin a toy. The Egyptians in 120 B.C. used steam to turn a device that was used as a child entertainer. Two thousand years later the energy source was applied to a time saving device. The Alexandrian thinker, or should I say game player, would have had little notion of the potential of this toy like invention. Imagine how completely history would have been altered if the Egyptian who had created the toy, or for that matter any who played with it, had thought to explore its potential beyond the context of play and entertainment. The essential question being 'what else could this power?'.

"Often the effort men put into activities that seem completely useless turn out to be extremely important in ways no one could foresee. Play has always been the mainspring of culture." (Italo Calvino) 1.



Physically playing with an idea may be the way to advance it. Many ideas have been generated and developed under what are considered playful or socially interactive circumstances. For example, numerous architectural ideas have been generated over a social drink, or whilst playing with plasticine pencils, card or glue.

A basic plasticine model that represents a very playful response to a serious design brief.



Section of the 'Green building'
Architects: Future systems
Engineers; Ove Arup. 2.

In play we tend to test the rules and the patterns that we regularly conform too. We tend to explore new boundaries and invent new possibilities.

"When truly creative people come up with a new idea, they do not reject it immediately for its flaws. They play with it, looking for strengths and sliding over weaknesses"
(Dr. David Campbell) 3.

Under the pretence of play we are not restrained by the pressures and formalities of the adult world, or by the swift and sometimes ruthless judgment of our creative acts. An explanation for our behaviour is not necessary as we are 'only playing', that is until we believe that we have produced an idea of notable value. The condition of play may be viewed as a less serious activity than the act of design. The designer may experience less pressure to have any immediate proof or justification for their creative choices. This may allow the creative thoughts to flow unhindered. The fragile nature of the idea is clearly expressed by C. Bower in the following passage.

"a new idea is delicate. It can be killed by a sneer or a yarn: it can be stabbed to death by a quip and worried to death by a frown on the right mans brow." 4.

Essentially within the realm of play, the regenerative idea has time to develop and grow beyond the intimidating frowns or the severity of judgment that may placed upon it within the domain of design. Play is another of the valuable creative techniques and methods available to the designer.

Practice at idea generation

Practice at idea generation is essential activity, architects can become more creative and better at sourcing regenerative ideas by becoming more and more aware of the regenerative processes and the activities involved in design.

"'There's no use trying,' said Alice. 'One can't believe impossible things.' I dare say you haven't much practice,' said the Queen 'When I was your age, I always did it for half-an-hour a day. Why sometimes I've believed as many as six impossible things before breakfast.'" (Lewis Carroll, Alice in Wonderland.) 1.

The ability to find good ideas is not a gift, it can be a learnt process. Everyone knows that practice makes perfect. It is important to exercise the creative brain in the same way as it is important for an athlete to exercise his or her muscles. The human mind is like a muscle when we don't use it we weaken its ability to function. It suffers from mental atrophy. To develop the ability to produce good ideas we need to exercise the creative brain. A good sportsman or woman only becomes an Olympic athlete through intensive practice and rehearsal. As Leonardo Da Vinci stated;

"Iron rusts from disuse; water loses its purity from stagnation and in cold weather becomes frozen; even so does inaction sap the vigors of the mind" 2.

Many great thinkers have capitalised on consciously summoned and driven creative thought processes, instead of allowing lethargy and complacency to rule behaviour. "Few people think more than two or three times a year; I have made an international reputation for myself by thinking once or twice a week." (George Bernard Shaw) 3.

Although it is recognised that creativity may be consciously summoned, it is not necessarily an easy task. It takes a great deal of effort to produce creative results. Michelangelo once said, "If people knew how hard I worked to get my mastery, it wouldn't seem so wonderful after all." 4. Albert Einstein said when asked how he worked, "How do I work? I grope." and how he obtained his ideas, "Curiosity, obsession and dogged endurance combined with self-critique have brought me my ideas." 5. The perception that creativity is an easy and contemplative task is a fallacy. Creative thoughts are the fruit of intensive labour. Thomas Edison said that "genius is one percent inspiration and ninety nine percent perspiration." 6.

In regenerative design architects need to hunt for ideas and inspiration. They need to keep constantly on the alert in case design inspiration comes their way, to seek ideas and go to where they are likely to find them. Although at times inspiration may seem uncontrollable the chances of finding it may be increased by enlarging the stock of ideas. A chance encounter may provide the basis for a new development, but the development will not be made if the designer is not aware, or prepared, to make the observation when it stands before them. Preparation of the mind is essential, and so is mental rehearsal.

"...Creativity and consciousness of procedures (process) and methods go hand in hand. If you become more aware of your position relative to what has gone before and what is yet to come, your ability to decide from both the broad view and the specific view is increased. If you become more conscious of the stages of the process you can become more accurate in your predictions of what to do next." (D.Koberg & J.Bagnall) 7.

Methods of regenerative association

This discussion shall examine the methods of association in greater detail, and explore the use of analogy, metaphor and simile to discover regenerative models. From the discussion a simple formula will be extracted, that may be used to identify and source regenerative ideas based upon association. The discussion shall follow the chain of associations that emerge out of the establishment of a connection between an object and a design problem. In a later discussion the appropriate and the inappropriate selection of an analogy, metaphor or simile will be discussed. The purpose of this section is to discover and gather useful knowledge about methods and processes of association that are applicable to regenerative systems.

Analogy metaphor and simile

Analogy (n.) *pl.* gies 1. an agreement, likeness or correspondence between the relations of things to one another; a partial similarity in particular circumstances on which the comparison may be based. (Macquarie Dictionary) 1.

Metaphor (n.) 1. a figure of speech in which a term or phrase is applied to something which it is not literally applicable, in order to suggest resemblance. (Macquarie Dictionary) 2.

Simile (n.) 1. a figure of speech directly expressing a resemblance, in one or more points, of one thing to another, as *a man like an ox.* (Macquarie Dictionary) 3.

All these three terms not only have the ability to describe architecture and reveal the nature of some of its more complex design intentions, but there usage also has the ability to consequently inspire the creation of a new design response.

"Metaphor has been of importance not only in literature and philosophy but also in science, where it has performed an important role in the development of new theories,.... Metaphor offers us a terminology for such assertions which is both meaningful and able to present novel meaning: it enables us to 'conceive more than we can currently say'." (D.S.Miall) 4.

In both literature and architecture a metaphor, analogy or simile is an assertion of another idea to a task. An interaction of thoughts used in order to suggest resemblance and develop a deeper view.

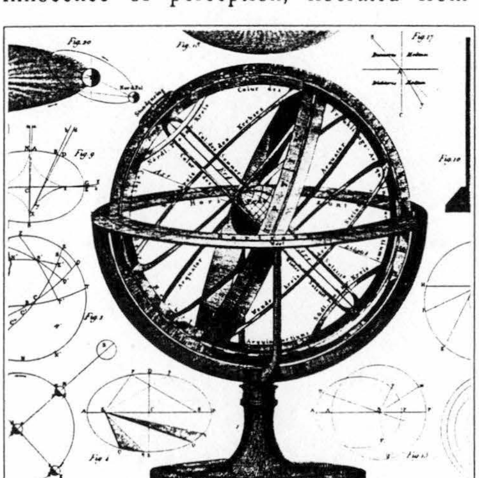
"Metaphors; similes and analogies are more than clever ways of restating the obvious. They are extraordinary concise devices by which a writer can convey new information." (J.R.Hobbs & R.C.Moore) 5.

Analogies, metaphors, or similies have the ability to generate ideas through the establishment of that initial link between an observed model and an architectural equivalent. Such comparative methods can awaken our creative mind and may develop into regenerative design solutions. To have control over these tools is of obvious benefit to the designer. As Aristotle stated. "The greatest thing by far is to be the master of metaphor." 6.

Analogies, metaphors and similes can assist the architect in unearthing regenerative models. They can be viewed as regenerative design tools, integral to the sourcing of reusable design ideas. To establish an analogy, metaphor or simile, the meaning and attributes of one thing are compared to the meaning and attributes of something else. In architecture the association is established because the characteristics of the model suit the architectural need. For example, the process may begin by finding a series of models that have a relationship to the new problem. The comparative models may then be examined for regenerative knowledge that applies to our new problem.

The process of associative problem solving may be summarised in the following way;
Stage;
1. Identifying and establishing a clear understanding of the problem.
2. Recalling one or more past problems that bear a similarity to the new problem.
3. Establishing the grounds of association.
4. Testing the potential application of the comparative solution to the new problem situation.
5. Further generalising recurring patterns into a reusable plan or approach for a range of other problems.

In another form, the discovery of regenerative ideas by metaphor, analogy or simile may be viewed as a spiral path of advancing knowledge. We may start with a base knowledge and then move up through the metaphor comparing what we know to what we don't know. The comparison made may result in new knowledge that forms a new base from which we can once again move forward. The process is like climbing a ladder. Each step in the associative process cannot be taken unless there is one below upon which to rest the other foot. Knowledge is attained when the designer considers what they have learnt from the comparative relationship. As Arthur Koestler suggests, "Every creative act involves .... a new innocence of perception, liberated from the cataract of accepted belief." 7.



8.

As an example consider the technological discoveries of Lord Rutherford, a molecular scientist, who by associative means was able to expand our knowledge and understanding of the atom. He did so by comparing the workings of the solar system to the structure of the atom. Rutherford took an associative leap and moved from the known to the unknown. He opened a door that lead to the discovery of new information and further comparisons, that could then be tested for their validity. There are likewise many architectural discoveries that have been derived from the fusion of associations. For example the notion to construct pneumatic buildings came from the analysis of both natural and artificial air filled structures. Both the atomic and pneumatic example is derived from the discovery of an appropriate model, they tend to suggest that a wide range of regenerative discoveries are reliant upon the initial establishment of either an analogy, metaphor or simile.

Decisions that relate to the establishment of associations can be based upon reason. In architectural design in particular we need to supply reasons to justify and support our ideas otherwise they may not be respected or understood by others. Consider in comparison the fields of art and science. In science no solution is taken seriously unless it is presented with supporting evidence that displays an impeccable procedure, and a base of methodical reasoning. In the fields of artistic expression this may not be considered necessary. We are likely to respect the haphazard processes that go on within the creative mind asking for little justification of the result. Architecture can be viewed as a blend of both disciplines. It requires the creative spontaneity of the artistic pursuits, plus to a degree the justification of the sciences. Architecture can be viewed as a justified form of art.

Logic and association

Logic - "A form of reasoning in which similarities are inferred from a similarity of two or more things in certain particulars" (Macquarie Dictionary) 1.

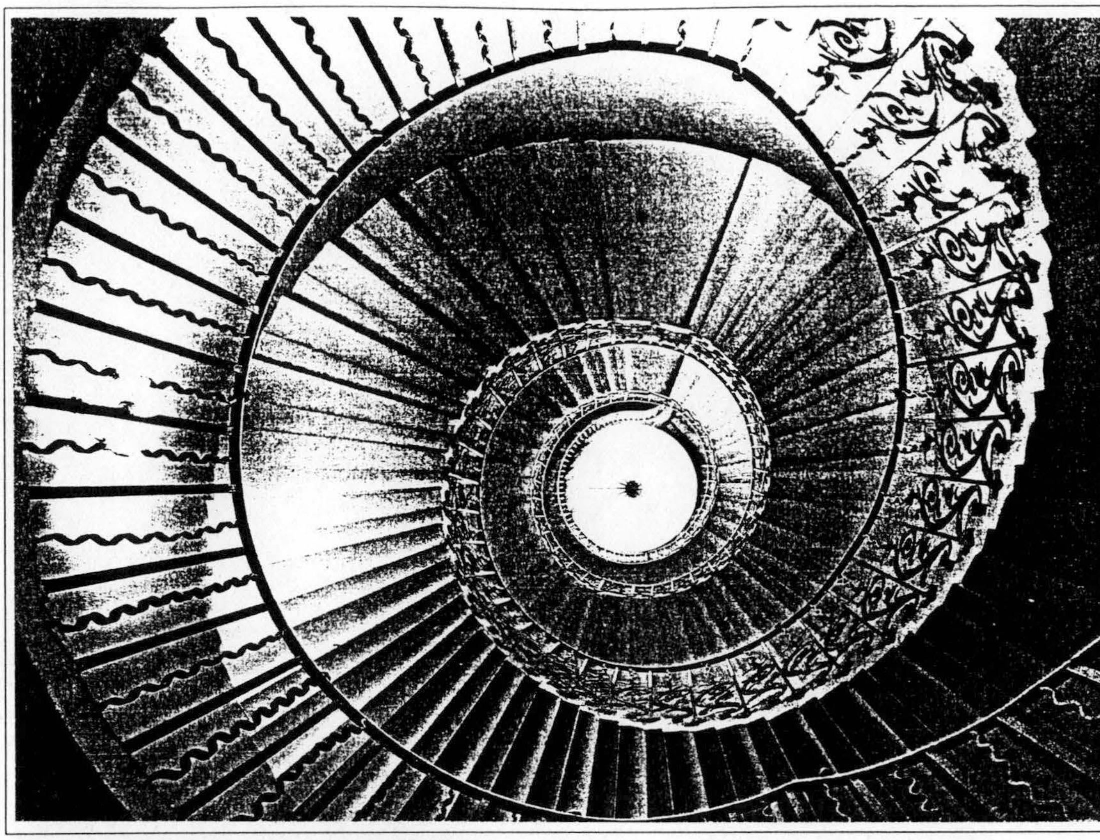
Logic can provide the ground rules and may furnish a structure to our decisions, we can use it to seek ideas and we may directly apply logical procedures to the method of association. It may not always appear to us that logic is the basis by which regenerative associations have been made, but more than often when we closely analyse the comparison we may find that the result will be that of a methodical procedure. Some comparative entities may appear quite distant to each other but when we understand the basis of the comparison the association may not be so illogical after all. For example we may say that a television is like a fish tank but we are unlikely to understand this comparative relationship unless we are also informed as to the basis upon which it was made. We may also need to be informed that this is so because we relax in front of both.

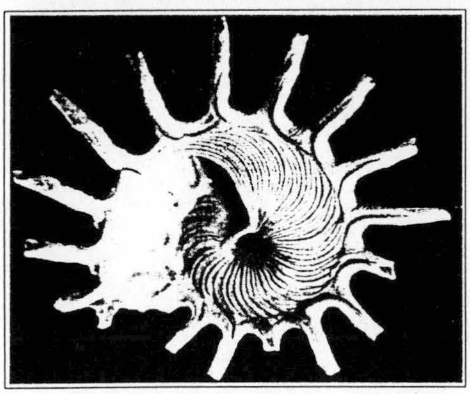
We may formulate, from the definition above, a structure that may be used to consciously seek and identify comparative analogies and appropriate regenerative models.

if	A = B
and	B = C
therefore	A = C

The following example highlights the value this simple associative formula to generate regenerative inspiration.

if a	staircase -	**suggests**	-	spiral
and a	spiral -	**suggests**	-	sea shell
therefore a	staircase -	**suggests**	-	seashell





Indigo Jones, The tulip staircase in the Queen's house, Greenwich begun 1616.
Its form is a cylindrical Helix. 2.

Sunburst Carrier Shell
(Stellaria solaris) 3.

By this comparative equation a great number and variety of provocative models may be established. The designer may stumble upon comparative models by chance, or consciously use such a formula to discover them.

Any point may be a starting place when using the model equation. If '**A**' is the starting point it may be necessary to discover a comparative object or quality. If '**B**' is the staring point it may be necessary to identify the comparative objects. For example, if '**B**' is flight, an association may then be inferred between birds and aeroplanes. The designer may look at the bone structure of the bird's wing, and discover regenerative knowledge about monocoque construction, or facts about negative pressure filled structures. This may be applied to aeroplanes or even buildings. Starting with '**C**' in the equation may set and limit the result. For example, the designer may only wish to discover things, about buildings, about staircases or aeroplanes.

The chain of linking associations

Patterns of association may be described in many different ways. They may be described under, cultural criteria, rational or engineering terms, or alternatively, in a literary and poetic manner. The variety of approaches may be enormous as patterns of association are closely bound to the individuals understanding and belief system.
As Paul Shepheard writes:

"Listen to those voices, Architecture is metaphor! says one. Architecture is a computer programme! says another. Its the voice of the underclass!, its Imagineering! - or it is something on the event-space-movement axis?. Can nuclear physics help? Can literature? What questions! What assertions. Its like listening to people fighting dragons in the dark." 1.

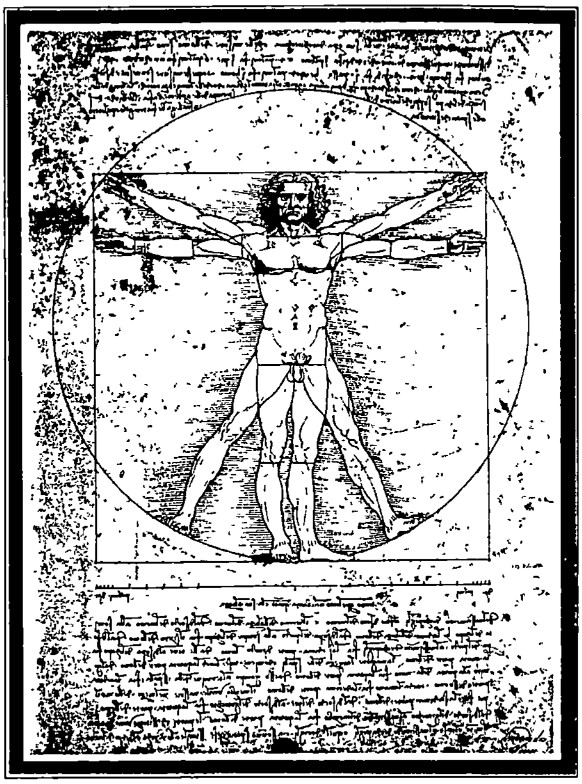
While it is relatively easy to describe a creative process after its occurrence it is very difficult to hypothesise its likely path. This is determined by the idiosyncrasies of the individual designer.

At the simplest level the decision making processes used in mathematics may be used to describe the patterns of association. Much work has been carried out by computer scientists in attempts to codify the steps and processes involved. To some degree this process is successful, in that many variables may be manipulated and modified to simulate different possibilities. These programs have yet to surpass human thought, as it can be seen that the grand masters of chess are still a match for the computers. This must reflect a human ability to make high quality and creative game plans, despite an ability to process fewer possibilities than the computer program. The rules in chess are quite simple in comparison to the decision making activities involved in design. The analogy however is a useful and has been used by Murcutt, and examined by Fromonot:

"..the metaphor is clear, in architecture the object rules and the pieces are prescribed. Each new game presupposes a fresh strategy applied in a sequence of logical decisions." 2.

Tradition is a strong part of the associative process. The designer may choose to draw elements from the immediate built environment or go further afield. For example, the area of Japanese architecture is a potential rich source of associate chains, the designer may wish to develop an idea based upon wood technology, this may lead to a discovery of Japanese joinery and be reflected in a final design that suggest Japanese origins. The analogical model tends to leave a distinctive flavour upon the final design result. It is the nature of perception that allows an associative process to be unique to the individual, reflecting their experiences and cultural background.

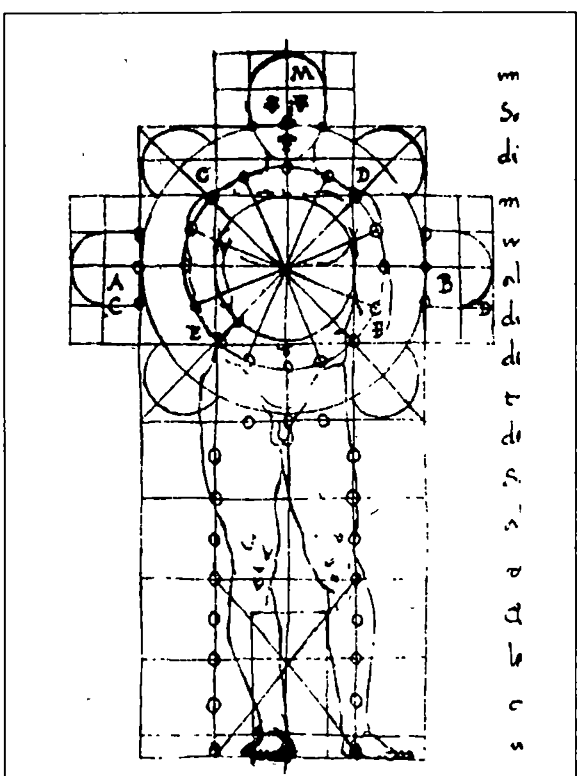
In the establishment of analogies, associations may be inferred from the resemblance of certain properties, and in turn these resemblances may establish a linking chain of other comparisons. For example, the relationship between the human body and the workings of a city may be initially determined by likening the way a city consumes resources, to the way a body consumes food. The architect or planner may then discover that this association brings to mind many other comparisons. For example, the circulatory system of the human body may be likened to the transport network of a city. The roads in the city decrease in size and increase in number, in the same way as the main arteries feed into the more numerous veins and then a prolific number of capillaries or minor pathways. Another step of association may lead to the establishment of a structural relationship between the skeleton that supports the body and the buildings and structures that form the city.



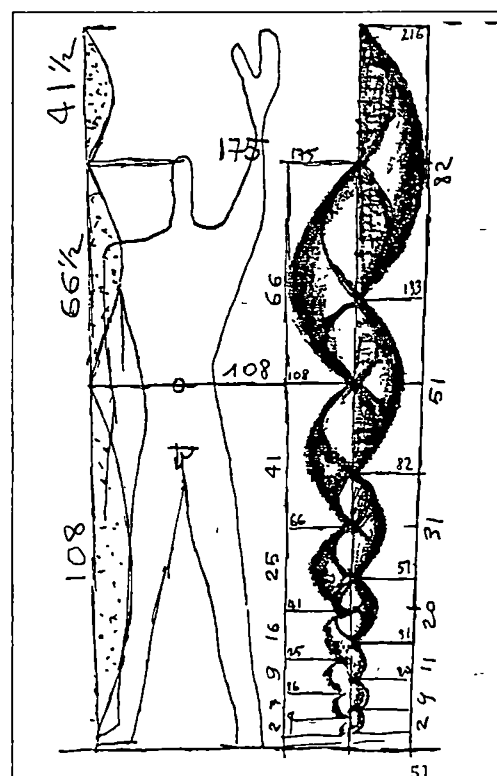
Like a body the city can 'grow' it can 'age' and it can 'die'. This is a very rich analogy as there are countless comparisons that can be made. From the associations the designer may learn a great deal about architectural concepts and design problems. This example also reinforces how the establishment of one comparative thought can feed a successive chain of transferable ideas.

The use of bodily concepts to inspire architectural design has itself been revived and regenerated many times throughout history. Bodily proportions have inspired the design of the first Greek and Roman temples, Renaissance churches, the Chinese Yin Yang and Feng Shui buildings, and the modernist structures.

Leonardo da Vinci, Vitruvian proportions derived from the human body, c.1490. 3.



Francesco di Giorgio,
Human figure inscribed in church plan. 4.



Le Corbusier, The Modular:
A harmonious measure to the human scale, 1954. A proportional system for architecture derived from the proportions of the human body. 5.

Conceptual understanding of the associative process may be further extended by its visualisation as a linking chain of comparative thoughts, derived from an associative model. For example, a concept is enriched by layers of associations in the following passage by Richard Leplastrier:

'Imagine our city as some living tapestry where the landform is the warp and the constructional elements the weft. Through time it develops a sense of oldness and charm. Things only become truly beautiful with appreciative use. Naturally over the course of years, it gets worn out in patches, so some locales need renewal, others only resuscitation. We can't make the sensitive decisions without respect for the warp and the weft; one has to understand the strands and all the underlaying layers of the place in order not to lose its cohesion or pattern." 6.

In this discussion each analogical discovery about the woven cloth, alters and enriches the core idea in some way. The designer tends to direct the comparative process and the outcome towards a predetermined and useful result.

One of the most difficult tasks is knowing when to end the chain of associations that emerge. It is of utmost concern that the associations do not over ride the architectural concerns. The architect needs to be wary of the analogy 'snow balling' beyond the control of the designer. It is an easy mistake to blindly follow the successive comparisons that may arise from the associative process, forgetting to reference them back to the design priorities. When there are many associations and reapplicable ideas, it is difficult to know when to make a break from the analogical model. Another possibility is that the architect may set off on another tangent, discovering a model that provides further regenerative inspiration. For example, the idea to select sailcloth for a roof may trigger an association with another artifact other than yachts, such as a bush walking tent. This new association may in turn uncover numerous regenerative details and ideas.

In conclusion analogy, metaphor and similie are creative tools of immense value, they open the doors of illustrative description and communication and tend to stimulate the creative mind on to further design thought and contemplation. The association between object and building may be established through a procedure of common sense reasoning and logic or one of emotive origin. It may be a process of analysis that promotes a linking chain of design thoughts and possibilities or one of intuition and subconscious responses. In both cases the design idea advances and develops as it moves along the links of the design chain. The thoughts become richer as the associative connections are added to the equation. There is no limit to the number of associations and regenerative ideas that may be overlayed in a comparative process.

Design obstacles

There is a great deal of design potential in the exchange of ideas across the fields of human endeavour. Discussed under this heading are those factors that may inhibit a regenerative process, or prevent the free exchange of ideas. The analysis includes how specialisation, interdisciplinary boundaries and the ownership of ideas, affects creativity and regenerative systems of design.

Interdisciplinary boundaries

There are numerous technologies that await rediscovery, that is, if the boundaries between the specialist disciplines are resolutely crossed. For an approach that encourages the exchange of ideas these barriers require analysis and discussion.

In the regenerative process designers source ideas from outside the domain of architecture, comparing objects not often grouped together. For example, the study of architecture is infrequently compared to the study of sea molluscs, but the field of marine biology may contain a great deal of knowledge about structural forms that is relevant to the architect. As the two fields are rarely aligned many regenerative ideas may be missed. For example, the structure of a sea shell may present the architect with an innovative building form.

Section of a Lamp Chank Shell, showing the articulated interior structure. 1.

As the bulk of knowledge has increased the ability of any individual to comprehend ideas across a spectrum of disciplines has decreased. What is more, new knowledge is increasing so rapidly that it is physically impossible to keep pace with all contemporary innovations, because of this, designers are forced to be selective in the knowledge that they pursue.

"...The rising tide of new knowledge forces us into ever-narrower specialisation and drives us to revise our inner images of reality at ever faster rates." 2. (A.Toffler)

Specialisation results in knowledge progressively becoming more and more disjointed. Under these circumstances it is less likely that the information revealed by a specialist group will be exchanged. The designer may miss the potential relevance of a new technology, because the discovery may only be examined within a tight framework and narrow mind set. The division of knowledge into academic disciplines creates artificial boundaries, such compartments are a human invention and they are not absolute.

"Nature has no watertight compartments. Every phenomenon affects and is affected by every other phenomenon." 3. (Theodore Cook)

Categorisation may be viewed as a significant inhibitor of the regenerative process. Specialists, do not often see beyond their own fields. The answer to a problem may be in another field of research, but it is unlikely that they will see it. Categorisation limits the range of ideas that specialists are exposed to, and therefore limits the ability to establish analogies and metaphors, and discover new ideas.

Compartments directly affect perception and creative responses. For example, a tree may be seen by different people in a different light. An artist may see its colour and texture, a biologist may see its role in the ecosystem, a forester may see its material worth. All these perceptions are valid responses shaped by the experience of the viewer. If an artist saw what a biologist saw in a tree, there may be an original and interesting response. The analysis of an idea or a technology, by a person with a new perspective, will open up new possibilities.

Every discipline has its own specialist terminology or jargon. This jargon may be another abrupt boundary to the understanding and the exchange of technologies. A technology discovered and developed by a specialist may be very difficult to understand by anyone other than another specialist involved in the same field.

"Although discoveries can be made without leaving your own chair, the normal technique for unearthing new ways for doing things is to travel outside your usual environment. This method suggests that travel can also take place in the mind. And that one way to find ideas is to mentally 'get out of town'. Allow yourself to take the problem to a new environment." 4. (D.Koberg, J.Bagnall)

Problems may be more easily solved if the designer is removed from the immediate context, and assumes an objective point of view. Those removed from the problem, often see it in a totally different light. It is possible to look at a problem too long, and become overly familiar with the details. The designer may then expect to see things in certain contexts, and in particular relationships.

"...People do not tend to ask any questions about facts with which they are thoroughly acquainted; they ask questions about unusual events" 5. (A.Koestler)

The specialist has a type of knowledge attained by focusing on a specific problem. The specialist uses their mind to analyse, diagnose and discover information, at a close range. Less frequently does the specialist stand back and observe or assess the significance of a full view, or in a regenerative context, the broader relevance of the discovery.

"The danger of all scientific work .... is the tendency to extreme specialisation." 6. (Max Muller)

Knowing too much about a single entity can reduce the ability to look beyond what has been learnt. Once a path is cut to a solution, it may be difficult to create a new one, as analysis may be directed towards the path that is know, or towards a routine of thought worn by previous thinkers. Sometimes, a level of ignorance can promote the discovery of a successful path, one that may not have been pursued, if the implications were realised in the first instance.

"Habits are the indispensable core of stability and ordered behaviour; they also have a tendency to become mechanised and to reduce man to the status of a conditioned automation. The creative act, by connecting previously unrelated dimensions of experience, enables him to attain a higher level of mental evolution. It is an act of liberation-the defeat of habit by originality." 7. (A.Koestler)

The knowledge discovered by a specialist's mind often awaits application by a less specialised or near-sighted observer. It may be assumed that most of the world's great technological discoveries have come from specialists, highly trained in their field, but this is not always the case. There are many technologies that have been developed by people unassociated with the field to which their designs and devices contributed. For example;

- Kodachrome film was developed by a musician.
- The ball point pen was invented by a sculptor.
- The pneumatic tyre was developed by a veterinarian.
- The automatic telephone was developed by an undertaker.
- The Wright brothers were bike mechanics.

As these cases demonstrate, a view from outside the field may be extremely valuable. Fruitful design does not occur in isolation. In biological terms, cross-pollination is necessary to create a new and healthy design response.

Ownership and the value of the idea

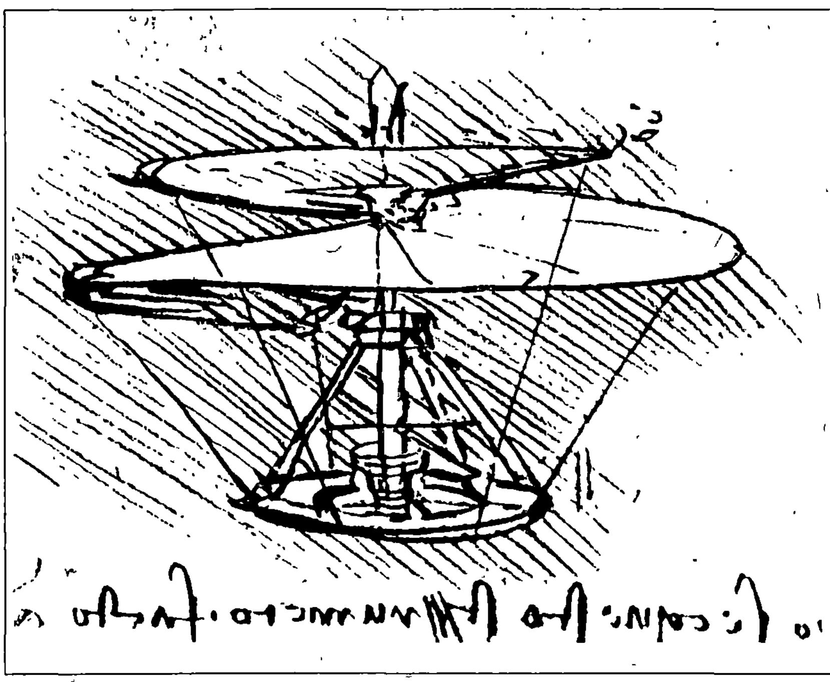
In an ideal situation the regenerative process is not limited by factors that confine the availability of ideas and inhibit the potential for development and improvement by another mind. Unfortunately the unbridled situation rarely exists. In our society ideas are considered a form of property. Humanity has a tendency to allocate a value to an idea, followed by a subsequent desire to protect this value. The valued idea has frequently taken a considerable amount of time and effort to develop, it is this time and effort that is measured. As David Pye observes in his book 'The Nature of Design'.

"Any change originated by man exacts a cost for him. The cost is reckoned in effort, trouble, time, often in running of a risk and enduring discomfort also." 1. (D.Pye)

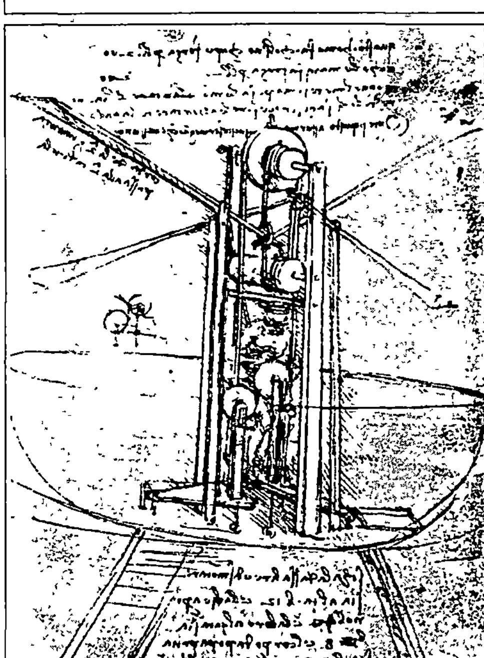
Apart from the relationship between an amount of effort and a value, there is also a subsequent relationship between this value and a potential monetary gain that presents very complex design issues. An odious fact is that in our culture time equates with money, and money controls much of our behaviour. Society tends to fiercely defend its valued property, and is less likely to share it with others. In the developmental stages the potential value of an idea can hamper its exchange between the professions.

Ownership, in a positive sense, may supply the developers of ideas with a security, and a reason to pump money and energy into the task of exploring their potential. To develop an idea may require a large amount of time and energy. If there is no perceived benefit in this activity, there will be little chance of the idea being developed. Ownership, may be viewed as an artificial device, designed to encourage the development of ideas. The system not only allows time, for the inventor(s) to recoup their capital investment, but also allows for the further development of ideas by setting expiry dates upon claims of ownership. Ideas pursued in this environment become directly linked to the desires of the market place, and may only be explored and developed if there is an associated profit to gain from their application. Monetary gain has, in our contemporary society, become one of the foremost motivations for design.

In contrast to the contemporary context, is the design context of the past. In the past creative activities were often pursued under very different and possibly more conducive circumstances. Many of the world's greatest discoveries were made by people who were not pressured to produce commercial results. Inventors, scientists, philosophers and artists were frequently supported by patrons, to concentrate on creative thought. Take for example, Socrates, Plato, Aristotle, Aquinas, Brunelesci, Galileo, Leonardo da Vinci, Marie Curie, and Einstein, all great creative contributors, directed not by the commercial application of their work, but by the pursuit of creation itself. This statement does not condone the character of the social class systems that gave these people the opportunity to experience creative freedom, but it does suggest to us that when commercial gain is not an immediate concern the mind has an ability to think outside the mainstream. There may be fewer closed doors in the creative scenario where we do not also have to consider whether the idea is marketable. Design ideas produced via such a method may not result in an immediate commercial application but nevertheless in the future the result may prove to be of benefit to humanity, and possibly adaptable to the consumer market. A desire for an immediate commercial result from design may be an unhealthy pressure on creative activity.



Leonardo da Vinci's aerial screw or helicopter. 2.



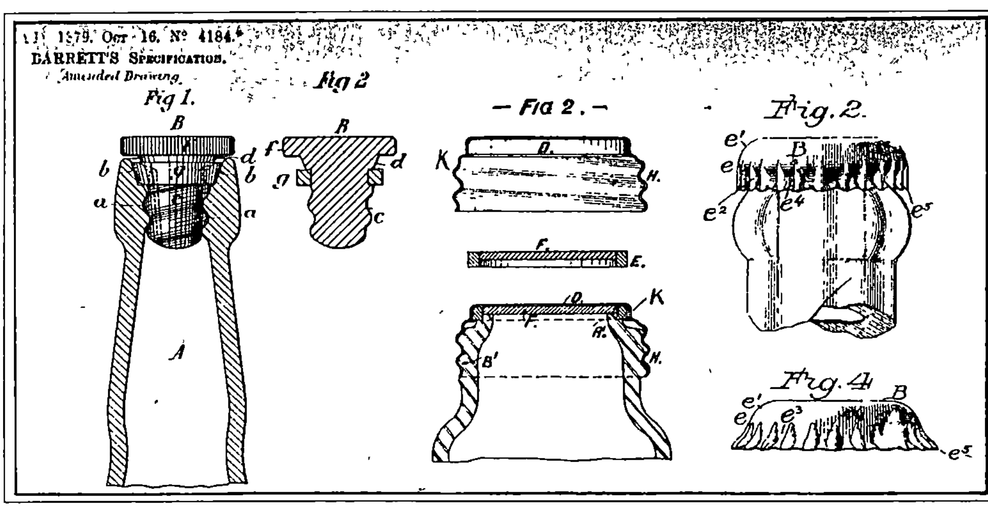
For example, Leonardo da Vinci's conceptual designs for a helicopter, inspired from an analysis of nature, had in their time no commercial application. Neither the need nor the technology was available to develop the idea. Leonardo pursued the concept for purely explorative reasons. Today, vertical flight and the ideas initiated by Leonardo have proven to be of great benefit to society, cleverly adapted to a range of commercial markets and products.

Leonardo da Vinci, Pioneer aeronautics. 3.

In the past the development of ideas, beyond the commercial realm, may have been easier due to the scale of technological development. Most of the materials were easily worked, and tested in what we would view as small scale laboratories. Today, the developers of ideas are often working with high tech materials and expensive lab equipment, far beyond the means of the individual scientist. These materials and machines need to be financed, before the modern scientist has a chance to develop a high-tech invention in a high-tech context.

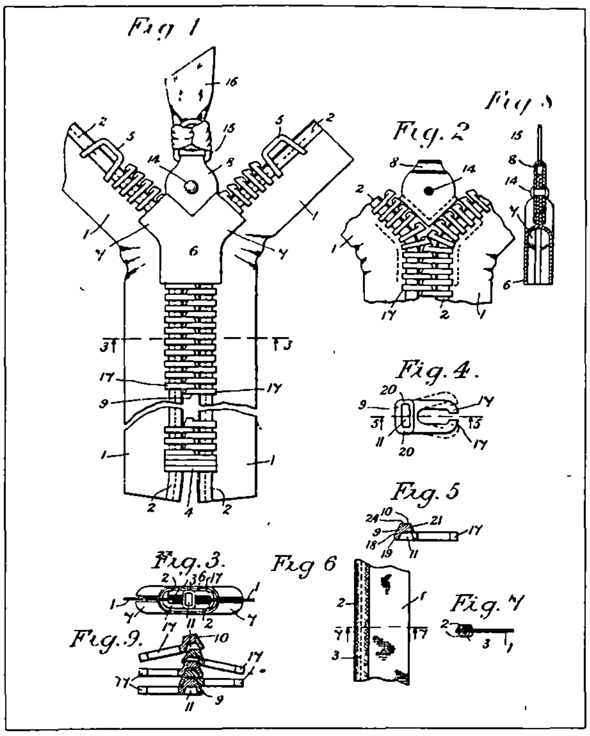
Protective devices

There are a number of ways to protect ideas, they include claims to ownership such as authorship, copyright and patents. These methods of safeguarding ideas have been designed to insure the potential value of an idea. The designer may choose one of these means to legally stake a claim to an idea. After doing so, the designer has ultimate control over the use of the idea and receives a royalty, or economic return on the idea, whenever it is used or applied. The designer has the power to limit the production of the invention and potentially push up its value. The reason behind this process and the reason why an idea is protected, patented or copyrighted is for commercial gain.



Patents : Internal screw stopper 4,184/1879, Barrett, Henry. External screw top with liner 12,629/1889, Rylands, Dan. Crown Top 2,031/1892, Painter, William. 1.

In Australia patents are issued by the Federal Government. They are good for 17 years, unless the patent deals with the visual appearance of the product, and then the patent may be good for 3.5 , 7 or 14 years. It is not attainable if the product has been on the market for more than a year, or has been described in publication for more than a year. A patent is only attainable if the invention differs in some significant way from the other items already under patent. The legal claim of copyright covers the form an idea is expressed in. The law will not copyright an idea in itself. Copyrights include everything from books, brochures, advertisements movies, records, pictures, graphic works, drawings and sculpture. A copyright is attainable from the Government Copyright Office. Under law a copyright is good for your lifetime, plus an additional 50 years. The third category of authorship is a legal status that applies to published material.



Zip fastener, Patent no. 12,261/1915
Sunback, Gideon. 2.

Patents today are extremely specific. This favours the regenerative approach. Legally a design or an idea requires to be only sightly different, before it can be disassociated from the original patent. The greatest difficulty in a regenerative process, is not in using the idea, and disassociating it from its ownership claims, but in obtaining the protected information that will provide the inspiration necessary for the birth of the new idea. In this sense placing a patent, or a 'lock' on an idea, limits its development. This may be viewed as inequitable considering that the 'locked' idea may have originated from another idea or source.

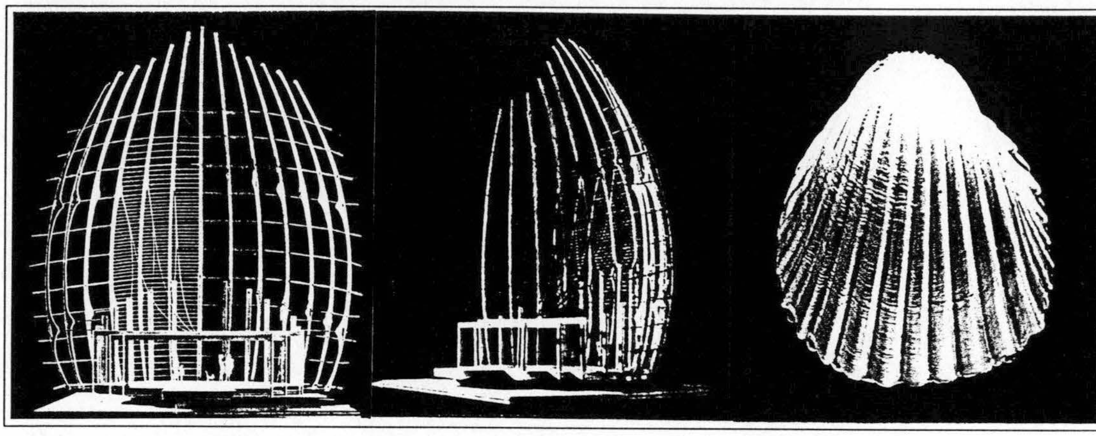
Ownership is an artificial system, within it there are many flaws and inconsistencies. For example, in an artistic sense it is not possible to photograph an apple, or draw a can of Campbell's soup, and then say that no one else is allowed to do so. In a scientific sense if two species of apple are crossbreed to produce a new commercial food stuff, the patent system applies. Under the system, it is possible to claim ownership of a plant extract, that may also be a life saving drug. It is also possible to claim ownership of a genetic variation in a plant or animal. In a design sense it is possible to claim a creative idea, if it is claimed before another. It is debatable whether anyone can really own the right to such things. Ideas may only be 'stolen' if they are truly original. A mark of shame would not be attached to the act of reusing ideas if it were recognised that ideas are more than often reused and recycled, rather than invented. All that is required is honest recognition and ethical behaviour.

Practical application of the regenerative idea

This section looks at the physical application of a regenerative idea and at the creation of the architectural object. Discussed are popular approaches that aid in the realisation of a regenerative idea into a built form. Examined are the use of models, in the development of regenerative concepts, and how models may give forecast to a design outcome. Another aspect is the manner in which material contact and new tool technologies inspire the development of 'new' ideas. The objective is to discover useful knowledge applicable to a regenerative process.

The application of the regenerative idea

In most instances of analogy, such as those in literature, the comparisons are simply inferred. In architecture the process is taken a step further. Designers analyse the inspirational object, identifying the relevant essence of the concept, and then physically reapply it to building.



Renzo Piano's cultural centre, Noumea, New Cal. 1991 and comparative shell structure 1.

The application of a technology will have a resulting aesthetic effect, directly affecting how the building is perceived. When transferring a technology into architecture the designer may discover that they transfer more than expected. Additional associations may follow with the reuse of a technological idea. For example, when transferring a structural system or a specific constructional detail into architecture (for instance, a shell structure from a sea shell), the designer may discover that a visual association with the original model is also established (such as a delicate and curvaceous form). The result of this association will likewise require careful preconsideration. For a regenerative result to be successful, all subsequent associations need to be appropriate to the new design task.

In another architectural instance, the designer may use a regenerative model to purposely establish an associative connection with the original model. An analogy may be employed to strengthen the relationship between a buildings purpose, function, or site. For example, in the design of a coastal weekender the architect may look for comparative inspiration in structural models, such as sea shells, sea birds, sea creatures and plants, in materials such as marine plywood, or in coastal structures such as light houses, jetties, tents, caravans, or sailing boats. Furthermore the architect may choose to seek a regenerative model in structures that deal with small spaces or temporary inhabitation.

The instalment of a regenerative idea may enhance an architectural response. A regenerative model applied to building design may express associated ideas, and provide an additional layer of meaning. For example, a house that looks like a tent suggests a lifestyle preference and may physically effect the way people perceive and behave within the building. A regenerative model may supply the designer with an inspiring source of technological inspiration and also a model upon which to strengthen the relationship between built form and context.

In the application of a regenerative model, it is essential that the concerns of architecture should dominate and direct the design, not the priorities of the model. It is important to retain the integrity of a design's architectural identity and purpose. On the diagram below it is necessary to stay on the side of architecture and building, and not to overstep the mark that separates a design from a copy.

The source <----|----> Architecture or building
A copy <----|----> An analogy

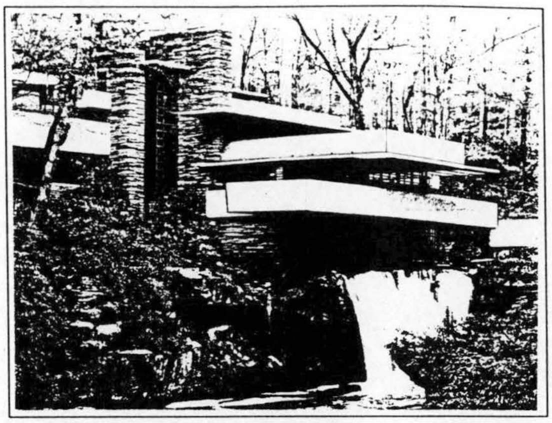
Appropriateness is a key issue in the interpretation of a regenerative model. It is vital that the model is appropriate to its new application, and that it sits comfortably within its new context. The application of a regenerative association is balanced, like a finely set scale. The scales may be easily tipped and the interpretation trivialised by taking the association too far. In this case, the design can be seen in the light of an imitation, rather than in the light of a regenerative interpretation.

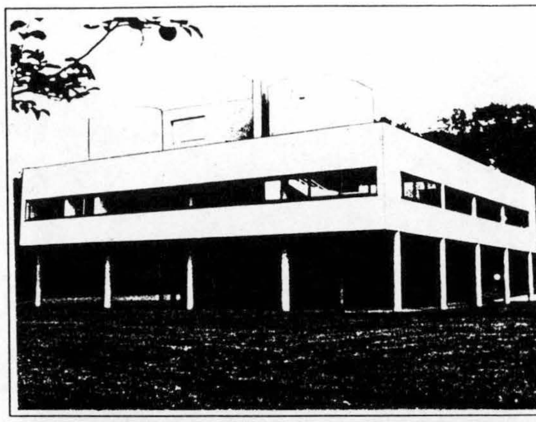
In a regenerative process it is essential to identify the limits of an analogy, and avoid going beyond the point where the comparison is no longer applicable to the new design task. A part of an analogy may work well, but if others do not they should possibly be avoided and perhaps another analogy sought. The layering of numerous extrapolations, from various sources, may often produce a finer result than the monogamous commitment to one source. A successful building that uses a number of concurrent analogies is the Sydney Opera House, by Joen Utzon. In this building each analogy is employed only to its level of appropriateness and benefit to the design. In the Sydney Opera House, the functional aspects were developed by an acoustical study, analysing the reflection of sound, the aesthetic qualities were interpreted from sails and yachts on the harbour, and the structural form developed from a study of natural shell and rib structures. In the design of the original interior much of the plywood and laminating technologies were derived from the ship building industry. These disparate regenerative sources were skilfully intermeshed to create a fine sculptural form, hinting at each of the design sources.

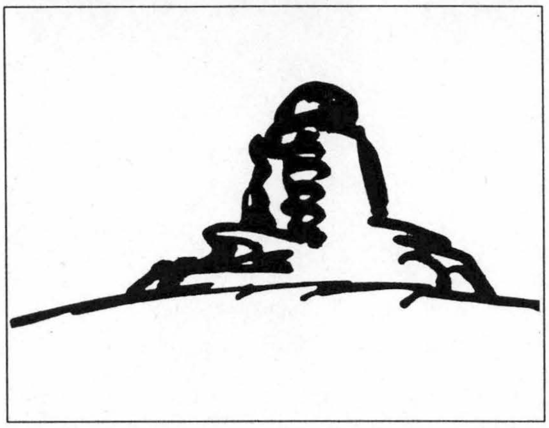
A regenerative element may be found in almost all buildings. The level of interpretation can vary from the complex and quite ambiguous, to the extremely literal. A literal analogy is the result of a direct, or very close interpretation of the primary generator.

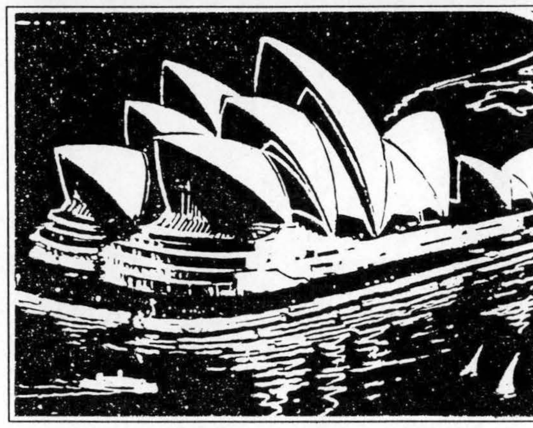
"Literal analogies are so termed because in all cases the resulting architectural forms match very closely the conformation of what the designer sees as the key features of the analogy." 2. (P.Rowe)

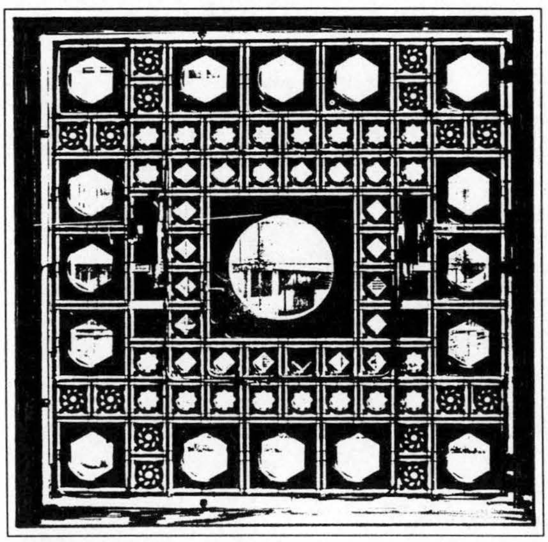
The series of representative images overleaf are organised in increasing order of analogical association. They vary from a complex interpretation to a very literal interpretation, that may be appreciated in only a symbolic or humorous sense. In the examples the designer has used the interpretation of either a structure, a functional feature, or aesthetic form to inspire design.

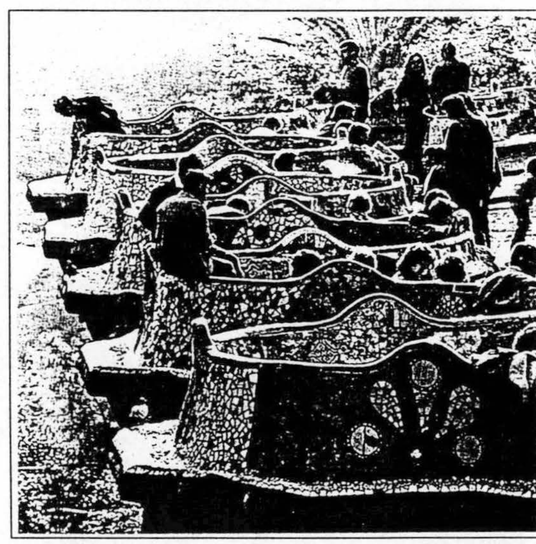


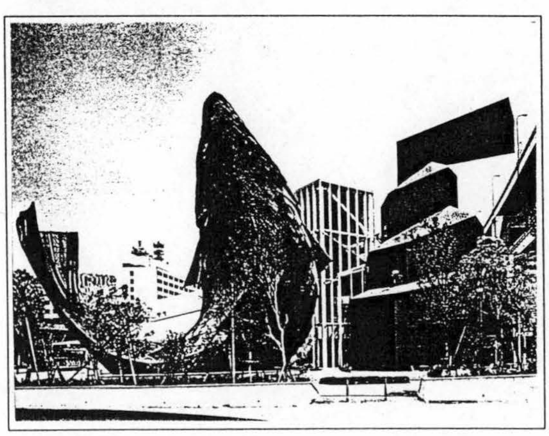


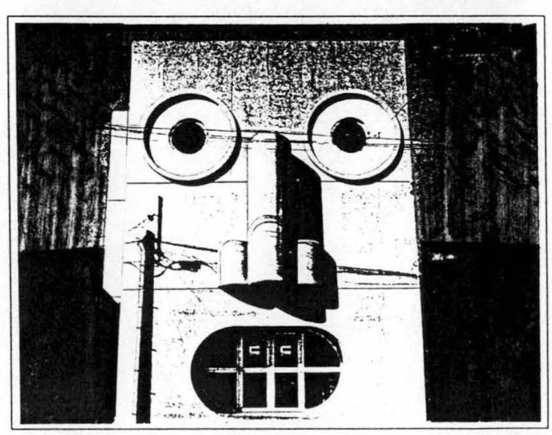












From left to right;

1. Frank Lloyd Wright, Falling water, 1936-37. (A structural and aesthetic interpretation)
2. Le Corbusier, Villa Savoy, 1929-31. (An aesthetic and functional interpretation)
3. Eric Mendelson, Einstein Tower. (An aesthetic and structural interpretation)
4. Joen Utzon, Sydney Opera House, 1957-73. (An aesthetic, structural and functional interpretation)
5. Window detail of the Islamic Embassy, Paris. (In a literal sense the analysis of a camera lens has provided the functional and technical knowledge for a building shading system.)
6. Gaudi, Parc Geull, (Aesthetic and structural analogies are used throughout the park.)
7. Frank Gerhy, Fish restaurant, Kobe. (A literal aesthetic analogy)
8. Kazumasu Yamashita, Face House, Kyoto, Japan 1974. (Based upon an aesthetic and functional association.)

In a process of regenerative design the architect may avoid an overly literal imitation of a subject, and instead interpret the essence of an idea. It may be less likely that a direct imitation will successfully relate to its new context. The original model is usually designed to suit a specific condition, when removed from this position, and applied to another, a degree of adjustment may be necessary. The response of an idea to context is similar to the way a plant responds to location. For example, a plant grown under low light levels may grow fine and pale leaves, if removed from this environment and placed in a bright sunny position the same plant may adjust to the new conditions and grow darker and denser foliage. Without such modification a design idea may not directly apply to a new task, as the context will directly affect the result.

Context is a variable that directly affects the success of a regenerated idea. In one context an idea may seem new and innovative, in another it may be cliched. For example, an architect may place a curved roof, or a pitched roof upon a building, detailed in a standard manner. In this example the architect may be imitating directly what has been done before, but they may not be burdened with criticism for imitative actions. The designer may believe that there is a limit to the number of roof forms that effectively shed water, or they may believe that such a solution is appropriate, due to its conformity to context, and its ability to strengthen the existing fabric. These factors add to the complexity of the design process. The question of how much alteration is necessary, for the idea to be considered 'new', is a particularly challenging one. A question that ultimately calls for a variable response.

In industrial design the resulting invention or 'new' idea may be reproduced many times. In architecture the situation is slightly different. A building, unlike the industrial product, is unique. It is designed as a one off, and produced in its entire form only once. If we examine a building closely, many of the components of the design are standardised solutions that are used by many other architects. Alternatively, they may be solutions to design problems that have already appeared in the work of the individual designer. In architecture it is the combination of details and concepts that is new, not each of the individual parts that compose the design. Legally a building, designed by an architect, may not be reproduced in its entire form, but the elements that constitute the design can be reused and often are. For the architect, it is these details and the palette of building materials that becomes a trade mark. Details are precious to the architect, as they distinguish a style and attract clients.

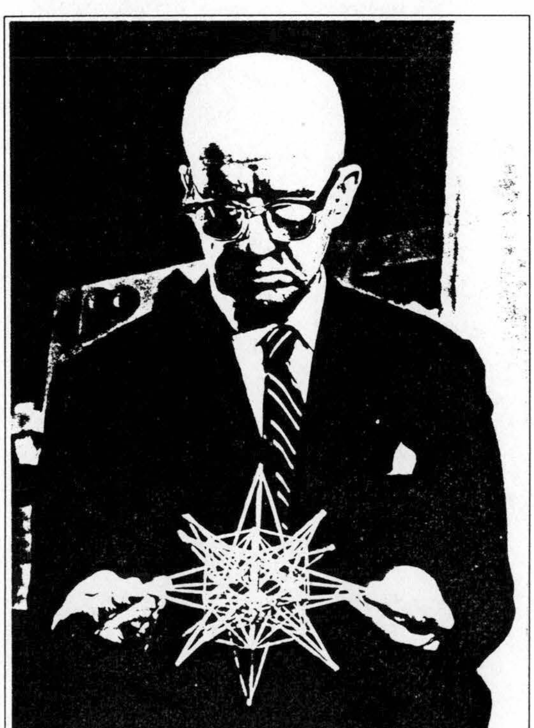
The creation of the regenerative architectural object

"We make a conceptual distinction, certainly between the activity of the architectural or an artificial *science*, on one hand, and the activity of the architectural, industrial or craft *design* on the other. But certainly, in the end, the practical interest of the scientific activity is in the *application* of findings to the design activity." 1. (P.Steadman)

The theoretical development of a regenerative idea has been broadly discussed. Another crucial aspect is the architects ability to fully realise the design and overcome the many difficulties involved in the creation of the built object. Models, materials, and tool technology are a part of the making process, and closely affect the design outcome and regenerative design process. This discussion relates to a later section, where the design and practical difficulties faced by Buckminster Fuller in the realisation of his innovative and regenerative design ideas are discussed.

In architecture the difference between a good idea and a creative success is in the application. Undoubtedly the architect will discover that it is the practical and applicable ideas that are the valuable ones. As Thoreau once said, "If you have built castles in the air.....that is where they should be. Now put foundations under them." 2. Ideas in the head are the first stage of a regenerative process, the second stage is translating these ideas into something useful and real. Until then the numerous ideas reserved in our minds are in Limbo.

To realise a regenerative idea the designer may need to examine how the original model was realised, as this may supply some knowledge reapplicable to the creation of a new structure. In the transfer of an artifact inspired idea, the original construction processes and the tools, may be reapplicable to the new constructional task. If the designer is planning to transfer an organic model into architecture, the objects form or detail may provide design inspiration, but it is unlikely that the designer will be able to use the same materials. In this case an option may be to search for parallels within the built environment, for material options, constructional techniques and design leads. An alternative may be to develop a new constructional process or composite material.



3.

"The model gives a true embodiment to a concept." 2. (R. Buckminster Fuller)

A model may be a representation of the relevant characteristics of reality. When we build a model we may move from the abstract closer to the real.

When dealing with complex regenerative concepts the architect may discover that what appears to work on paper or in the imagination may not work in application. This may be due to the fact that it is not always possible to foresee and calculate all aspects and conditions, especially when dealing with innovative designs or those based upon organic models. An experimental design may require testing in three dimensional form. The physical model, or computer simulation, may be the only way to conclude whether the idea will succeed or fail. The model is just one step away from the real building, in both a constructional and an aesthetic sense, and therefore may be a useful tool to test a regenerative design response. The drawing may distort our perception but the final product can not deceive, as it stands before us in its true proportion.

It may be viewed as important to bring ideas into reality. "The act of converting an idea into lines and other marks on paper often excites the mind and the imagination, encouraging the flow of creative thought." 4. (S.Lambert) If the observations expressed by Lambert are extended, the designer may conclude that there is a similar capacity to stimulate the mind by taking the two dimensional marks on paper and developing them into a three dimensional model. Realisation undoubtedly has the potential to inspire new thought. This is very similar to the way a generative idea may inspire the imagination. When constructing a model the designer converts the object into something that can be seen, tasted, smelt, or heard. The numerous sensory tests that may be carried out on a model will allow the designer to actively improve the idea.

Like the regenerative process itself, design by model precedent is a sound and safe process. If the result has worked once, logic indicates that it will have a greater chance of working again. The designer may be selective, taking only the working aspects, discarding or modifying less successful aspects of the design. Under such conditions the designer may increase their chances of success.

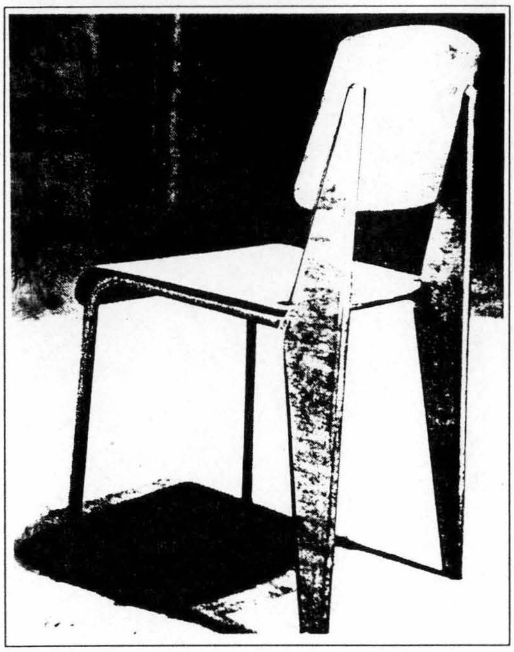
Hands-on material contact in the development of regenerative ideas

Architecture has an inseparable link to the physical act of making. The origins of the term 'architecture' supports this statement. The first architects were masters of a craft, and played an active role in the process of building. The word 'architect' is derived of the Greek term 'Arckhiteckton'. Broken into components, Arckhiteckton means Chief-builder. Arkhi, (arkhos) meaning superior or chief, and tekton meaning builder. Some architects today tend to separate themselves from the physical process of building, and by doing so, losing an opportunity and an intimacy relating to an understanding of building materials. The designer surrenders the opportunity to develop regenerative ideas from their distinctive qualities.

"There is ...... in all artistic creation a characteristic *tension* between the man and the material in which he works ...... The artist literally *wrestles* with his material, while it both resists and nourishes his intention ..... He finds himself constantly excited by the qualities objectively presented in the material which it is his aim progressively to discover." 1. (Max Black)

Hands-on material contact may directly inspire regenerative activity. For example, twisting a sheet of plywood may inspire a new form, or physically taking a product beyond its present use into another context may inspire a new application. The results of this approach may help to intimately link the design to the materials and constructional processes explored. It may uncover a totally different solution than a two dimensional design process.

There are many designers who have utilised experiments with different materials. For example, Jean Prouve a European furniture manufacturer and designer, found a great deal of design inspiration in the character of many of the new metals and processed woods of his time. He took these materials beyond the contexts under which they were designed and applied them to innovative furniture and architectural design. Prouve stated that his furniture was the direct result of material and constructional considerations, and that the resulting forms were the impersonal consequence of the materials explored, and the structural and dynamic forces, that the furniture was designed to resist. 2.



Prouve's furniture brilliantly explored and extended the potential of the modern industrialised materials and production processes techniques whilst retaining an elegance in sculptural form. 3.

Of note is Prouve's belief in the comparative nature of the design industries. This is possibly one of the reasons why he so successfully discovered, applied and developed the use of many new and different materials to unprecedented tasks. As Prouve stated;

" There is no difference between the construction of a piece of furniture and that of a house". 4.

The furniture industry has often been a testing ground for new materials. There are many architects who have trialed the use of materials in furniture design, before applying them to architectural applications. The period between 1915 and 1935 is indicative, as it witnessed the testing and reapplication of many new materials, such as composite wood products and metal alloys. The character of these materials supplied the inspiration for many modern architectural designs. For example, Gerrit Reitvelt, the De Styl architect, was greatly influenced by modern material processing techniques, constructional developments and the standardisation of products. In an almost 'Dada like' regenerative sense, Reitvelt applied standard, 'off the shelf' products to both furniture and architectural design. Also from this period are Marcel Breuer, Le Corbusier and Eileen Gray. These designers are renown for exploring and extending the use of tubular steel in furniture design and architecture. With the help of this product they introduced lightweight, durable and cantilevered structural forms to the design industry.

Materials themselves tend to undergo regenerative development. For example, the work of Adolf Schnecks is a vital link in the development of plywood. Schnecks established a research section at the Stuttgart School of Applied Arts where he developed composite wood boards such as 'plywood' and 'blockboard', as they came to be known. He also developed new methods of veneering and jointing these materials together. Schnecks's discoveries have had an enormous affect on design over the past sixty years. In structural and aesthetic terms these technologies have transferred to and influenced, furniture design, interior design, architectural design, aeroplane design, yacht design, and so on. The regenerative application and development of these materials is extensive. Plywood has extremely ancient origins. The process of veneering was developed long before the 1930's, it was simply rediscovered by the modernists. The art of veneering has been known for at least 5000 years. The Egyptians used it in their furniture.

Sitamun's Throne, A carved and guilded chair of the 18th dynasty (1567-1320 B.C). The throne is veneered with an unidentified tropical timber. 5.

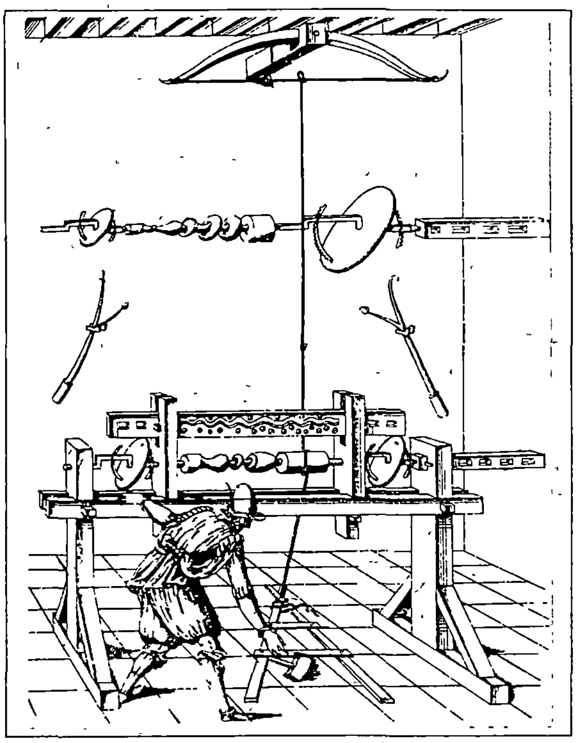
Timber was scarce in Egypt, and it was usually of a low quality. (The timbers indigenous to Egypt include tamarisk, siddler arcacia and carob and the date palm). As a result the Egyptians imported a great deal of timber to use in the construction of their fine furniture. Particularly for the construction of royal thrones, stools, beds and burial cases. The Egyptians imported timbers from Syria, including cypress, cedar, ash and box, and imported ebony from Ethiopia. The ebony was probably the most highly prized timber. Importing it was an expensive and a difficult business. To reduce the costs involved the Egyptians developed techniques to cover the less prized local timbers with the highly valued exotic and imported species. In this form the veneers do not have a structural function, as in plywood, but there are clear regenerative connections between the two. As another example, Roman shields were at times constructed of woven veneers. In this case, as in plywood, the strength of the shield is due to the crossing of the grain.

There are many architectural discoveries that have been based purely upon the reapplication of materials. Architects have discovered numerous applications for materials such as sailcloth, marine plywood and aluminium. For example, the use of aluminium was developed by the aviation industry. Its lightness and weather resistance was observed and admired by building designers. Subsequently the material was reapplied to the building industry.

Whilst the production of materials and constructional processes has improved vastly, the designers involvement with them has diminished. History suggests that designers may benefit greatly from a direct involvement in the construction process. A detailed knowledge of materials, that results from this direct contact, may allow the designer to adapt and use materials in new and innovative ways.

Tool technology

The development of new tools is closely associated with the development of materials and the advancement of technology. A tool is an essential item that is necessary to create and facilitate technology. The development of tools has an intimate relationship to the regenerative process.



Besson's ornamental turning lathe, 1578
1.

Tools and technology develop in conjunction with each other. They have a direct proportional relationship. The more advanced the tool is the more advanced and refined the product will be. There is a great deal of evidence to support this observation. For example, during the 1860's the introduction of new mechanised tools greatly affected the furniture, shipbuilding and architectural industries. The technological advances not only quickened the process of production, making items cheaper, but also allowed craftsmen to produced finer and neater products.

Many 'new' technological options have been opened by the development of 'new' tools. Tools allow the designer to create objects of greater precision. They increase the ability to carry out tasks neater, more precisely and faster than without them. Tool technology has been known to rapidly cross interdisciplinary boundaries and promptly benefit a wide range of industries. For example, rotary cutting was first developed in the shipbuilding industry in the 18th century by Jeremy Bentham. The original design for the circular saw was soon improved upon by Marc Isambard Brunel, a furniture designer (who is also famous for his block-making machine). From the shipbuilding industry the circular saw found a role in the furniture industry, and in turn a role and an application in architecture. The circular saw has been transferred to a wide range of uses, in this sense the technology has been improved upon in a regenerative way.

New tools not only have the ability to open up new design and technological possibilities, but they also have the ability to close other regenerative options. Hand working skills and traditional knowledge is rapidly lost when there is an easier way to carry out a task. For example, there are fewer people today who know how to hand split a paling or hand cut a dovetail joint. The skills of our forefathers may be rapidly lost in the wake of a new tool. The new tool may open up a new design option, but it can just as decisively close off other design possibilities.

In most instances we tend to do what is easiest when using a tool. A mechanised tool cuts quickly in a straight line. The designer will tend to carry out what is easiest before considering other options such as tenoning or dovetailing the joint, which will obviously take more time and skill to create. What is easiest is not always the best solution. It may save an amount of time but it will not always save materials or produce a stronger joint or structure. In reference to this point laser cutting joinery machines have been recently released on to the market, making the use of joinery details more economically viable. Once again the problem has been solved by technology. Now that there is a technological means the architect can once again consider dove-tailing as a design option.

Tool technology may be viewed as a gauge that controls the realisation of ideas. The tools available tie the architect to reality and limit the designers ability to apply and create ideas in a physical sense. A real task, in the regenerative process, is seeking a way to achieve the desired result with the technologies available. The designer may, for example, wish to transfer a natural structural principle, such as the observation that an increased internal pressure in the bones of a birds wing increases the strength to weight ratio of the structure. This observation may only be recreatable when the technology to create hollow sectioned and air sealed members is available.

On one hand technological competency can restrict and limit architectural design, but on the other it can provide the inspiration and enlightenment for architecture. This effect is identified by R. Scruton in the following passage.

"What is possible in architecture is determined by the extent of human competence....Consider, for example, the discovery of reinforced concrete, and Maillat's use of it in his well known bridges, which curve through the air across ravines where no straight path would be apt or possible. The artistic consequences of that technical discovery have been of enormous consequences." 2.

When transferring a regenerative idea the means of installing the idea needs to be considered. Tools have a complex relationship to the regenerative approach. They can inspire creativity, they can be shared in a regenerative sense, and they can act as a gauge, controlling what is technically possible.

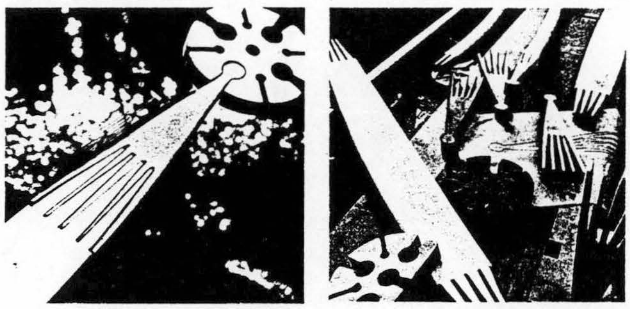
Fixity of Scale

When applying a regenerative idea the designer may be confronted by the problem that sizes tend to have a certain fixity of scale. The design model is not only a representation of reality, but it is subject to laws that reflect its scale. This affects the way it behaves when being tested.

The environmental forces governing a structure, have a close relationship to scale. The active force, be it gravity, surface tension, or van der Waal's forces, changes in relation to scale. At a human level gravity is the dominant force, for an insect it is surface tension, at a cellular level, van der Waal forces and Brownian motion become critical. An idea transferred from one scale to another may not perform as well under the relevant dominant forces.

The strength to weight ratio of a material is an aspect particularly related to scale. A sea shell of a millimetre thick, spanning five centimetres cannot be translated into a calcite shell structure a metre thick, spanning fifty metres. It would collapse under its own weight, as the internal cohesive strength of the material could not cope with the applied loads. The literal interpretation of this structure may not be successful, but a translation may be develop into a successful result.

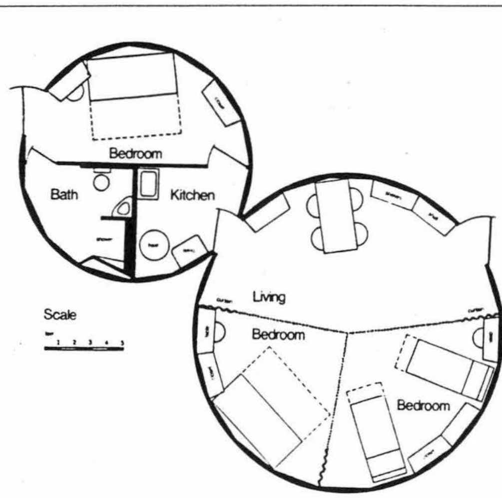
As suggested earlier, when reinterpreting a natural structure, it may be unsuitable to reconstruct the new design from the same material. If increasing or decreasing the scale of the original model, the original materials may not be applicable to the new application. When translating a structure the architect may be confronted by scalar transition problems. The architect may chose to reinterpret a timber structure at a larger scale, but timbers can only be grown to a certain size and length, with strength being exponentially rather than linearly proportional to cross sectional sizes. If designers go beyond the normal scale, they may have to seek an alternative material. In another instance if the designer wishes to reduce the scale of an object they may find that the members can only be made so small otherwise they may be weak at the ends, (that is if joined by traditional means). In this scenario we would have to seek a new joining system or a different material more appropriate for the construction of fine joints.

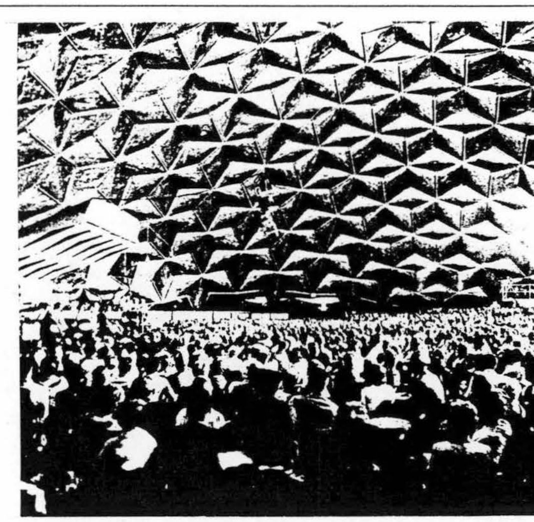


Renzo Piano, fine aluminium and timber joints for the IBM Travelling Pavilion. 1.

When increasing or decreasing the scale of a regenerative idea there are proportional factors that need consideration. A smaller structure can tend towards much finer and lighter members than a larger one. For reasons of safety there is a tendency to increase the size of structural members in larger buildings. Engineers require a much higher level of structural rigidity and resistance to load as it is obviously far less acceptable for a tensile stadium cover to fall in upon us than a small tent. A change in scale may alter the aesthetic result and potentially destroy the qualities of the original model that the designer may have admired and tried to emulate.

In another architectural instance a change in scale may interrupt the function and use of the building. For example, the architect may wish to transfer a structural form to a new application, at a reduced size, but the designer may discover that the structure then intrudes upon the function, as found in many smaller dome shaped buildings. A similar problem may be encountered when increasing the size of a regenerative model to a larger application.





Floor plan of double Dymaxion Deployment Unit, R.B. Fuller. 2.

Concert seated at the first Kaiser Dome on Honolulu, R.B. Fuller. 3.

It is evident that original sizes have a certain fixity, that is attributed to form, to purpose, to function and to the materials used. It is important to be aware of these aspects when exchanging and altering the scale of a generative design model.

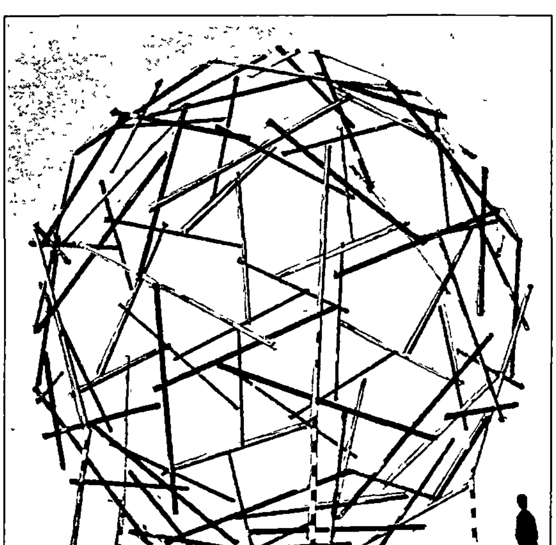
Section D: Guiding Principles

To further illuminate the design principles, Section D firstly discusses the work of the notable designer Robert Buckminster Fuller. Many parallels may be drawn between Buckminster Fuller's approach and the regenerative processes already discussed. A selected range of his work will highlight a number of regenerative issues. These will be translated into design principles, along with regenerative issues discussed earlier. The summary of the design principles is intended to aid in the sourcing, in the development and in the application of regenerative ideas. For the architect willing to employ a regenerative approach the principles may improve design judgment.

Robert Buckminster Fuller

A case study

In many of Buckminster Fuller's creative pursuits, the approach used could be described as regenerative; he frequently applied a design model to develop further ideas and design technologies. Buckminster Fuller often reapplied ideas and technologies developed by others, or himself, to previously disassociated fields or design contexts. He was not afraid to look beyond disciplinary boundaries for design inspiration or design applications. The breadth of Buckminster Fuller's design thinking made him famous. He contributed new ideas, new structures and technologies to; architecture, engineering, automobile design, cartography and mathematics.



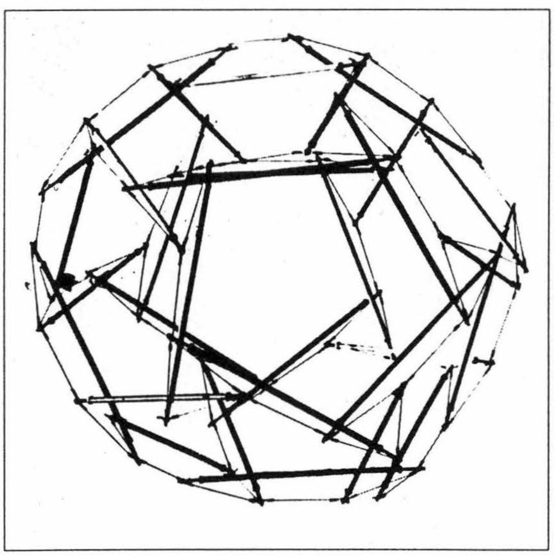
Ninety strut tensegrity enenticontahedron (90-sided figure) Princeton University, 1953. 1.

This first example of Buckminster Fuller's work was designed in the early 1950's. It is a remarkable structure and possibly one of Buckminster Fuller's most profound. The tensegrity sphere is derived from an analysis of the structural forces of tension and compression translated into an innovative structural form.

The tensegrity sphere was the result of an interpretation and a structural application of two basic natural forces. Buckminster Fuller often declared that he frequently began a design by starting with a broad study of the Universe, as an organisation of reusable principles. When describing the tensegrity sphere Buckminster Fuller stated:

"I am not trying to imitate Nature, I am trying to find the principles she is using." 2.

Buckminster Fuller had an exceptional ability, when it came to discovering exciting and new structural principles, but in the application of these discoveries to practical design tasks the results were at times less successful. The tensegrity sphere falls into such a category. It represents a design technology that has not proceeded beyond the level of a constructional experiment. At first appearances this fascinating structure may appear to have an architectural application, but almost half a century has passed and as yet no one has managed to successfully apply the discovery to architecture. On closer examination it appears that there is a fundamental problem that prevents the transfer of this technology to architectural design. The obstacle being, that the context in which this design technology performs, is in conflict with the context in which architecture exists. Architecture is inevitably restrained by the forces of gravity, the tensegrity sphere is not. A tensegrity sphere performs best as a floating ball without gravity to inflict a downward force upon its finely balanced structure. The sphere exists in a delicate equilibrium where the direction of forces are always 'in' and 'out'. In antithesis, is the standard architectural structure, affected by 'up' and 'down' forces. Both structural forms are reflective of the dominant active force affecting them. For example, consider the images below.

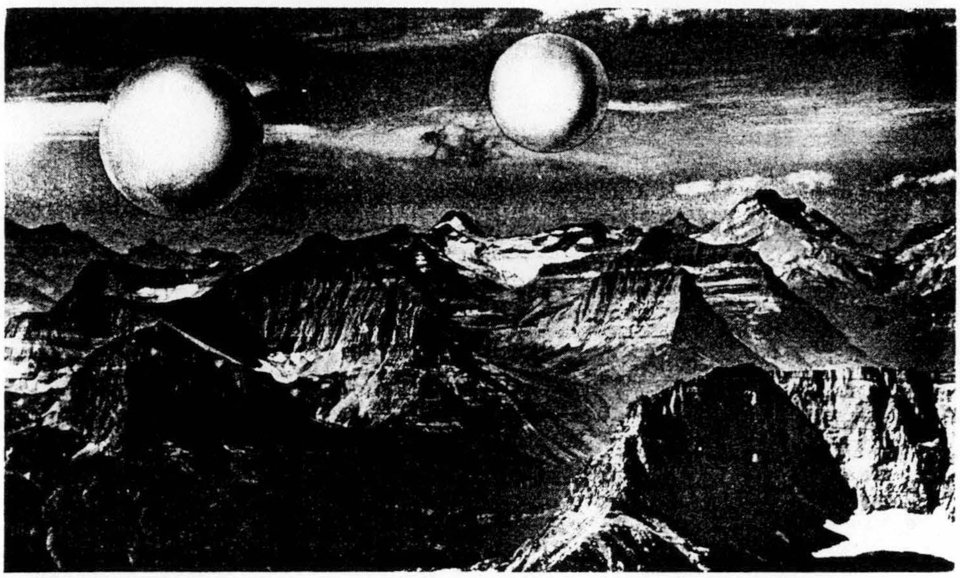


Tensegrity tricontahedron (30-sided figure) 3.

The Capitol, Washington, initial building 1792-1827, dome 1855-56. 4.

The tensegrity sphere has only a limited application when forced into a gravity bound context. This observation highlights an important issue. The results of a regenerative design transfer may not be as successful if the reallocated idea is forced into a design context into which it does not belong or sit comfortably. It is essential that the new context into which an idea is installed has a comparative relationship to the original design context. The tensegrity sphere may find more appropriate design applications beyond the constraints of gravity, such as in outer space. The structure could possibly be applied to space station or satellite construction, as there is a closer association between the generative model and the application or design context.

Buckminster Fuller had a similar design vision for the application of his geodesic structures. In a geodesic structure all the elements are combined, in a manner similar to the tensegrity sphere, to form an integrated shell with an exceptionally high strength to weight ratio. Buckminster Fuller visualised the construction of a number of one-mile wide floating geodesic spheres. When complete the weight of these structures would be far less than the weight of the enclosed air. The ratio of air to structure in a half mile wide sphere is 1000 to 1. Buckminster Fuller calculated that with a warmer internal atmosphere of only one degree Fahrenheit the structure would float. If the spheres were a mile wide they would be capable of carrying the weight of many thousands of passengers. He envisaged that these spherical 'clouds' could float around the earth at preferred altitudes or be anchored to mountain tops.



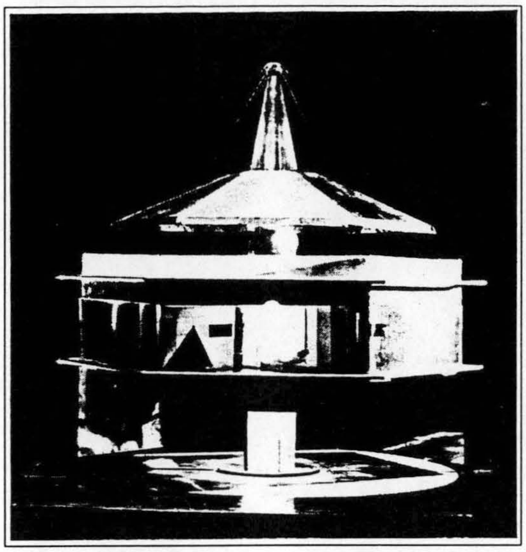
Floatable cloud structure, Buckminster Fuller. 5.

Buckminster Fuller's grand vision of floating geodesic spheres may be possible in theory, but unfortunately they do not appear to be possible, practically. This observation highlights another regenerative issue. It suggests that the transfer of design ideas and technologies are limited by the constraints of the physical world. At present, it is not possible to create Buckminster Fuller's floating geodesic spheres, as humanity hasn't developed the required technologies, nor the desire or need to construct them. Often a delay is required to translate a scientific discovery into useful architectural form. In many cases specialised tools or materials may need to be developed before a design idea can be realised.

Geodesic and tensegrity spheres do not conform to traditional architectural models. Both these structures are unusual, in that they have neither a top nor a base. It is difficult to find comparable architectural models. This observation suggests that a regenerative concept may be more successful if it fulfils emotive and practical needs, and does not disrupt basic human perceptions of what constitutes a shelter.

These examples suggest that whatever has the potential to limit architecture, be it a constructional, physical, emotional or functional constraint, will have a similar ability to restrain the application of a regenerative idea. If a generative design idea performs under similar circumstances, and suffers from the same design constraints, it may be more easily transferred into an architectural context.

Architects source a great deal of constructional knowledge to other fields of design. The exchange of building tools and techniques is common practice. For example, many improvements in timber processing have originated in the British ship building industry, including such common place tools as the circular saw. It seems inevitable that any invention, with the ability to increase production and produce a finer or neater product, will rapidly transfer to other related design industries.

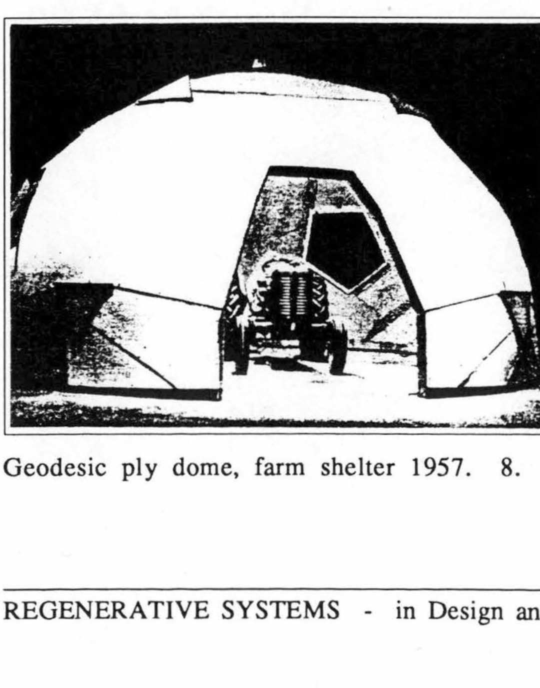


There are many instances in Buckminster Fuller's work where the transfer and exchange of tools and construction techniques, in the development of design prototypes, is evident. For example, the Dymaxion house borrowed heavily from the aviation and the ship building industries. This is clearly visible in the design result.

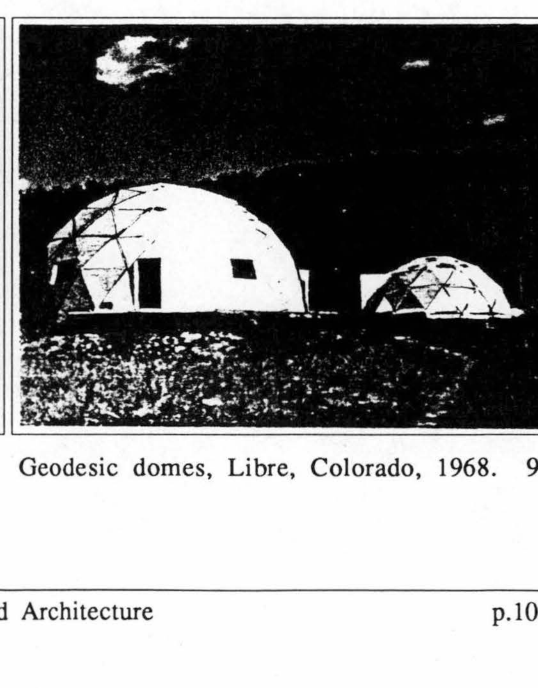
Dymaxion House project, 1927.
Buckminster Fuller. 6.

Apparent in Buckminster Fuller's work is a very strong emphasis on knowledge gained from the generative model. It is essential that in the process of intermeshing ideas and technologies that a dominance, by the generative model is avoided. A constructive model will not disrupt the building purpose, its structural stability, or the aesthetic design result. Measuring the success of a building may be a matter of personal opinion, however some generalisation can be made. The designer is always faced with the problem of balancing the many elements that constitute an architectural success.

In the application of the regenerative model the concerns of architecture should dominate and direct the design, not the priorities of the analogue. Consider the following geodesic house and garage, in the light of these observations, and as assessed under the criteria of firmness, commodity and delight. (Wonton) 7.



Geodesic ply dome, farm shelter 1957. 8.

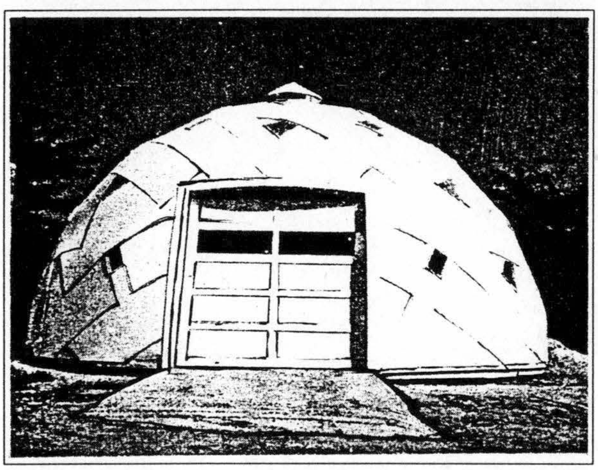


Geodesic domes, Libre, Colorado, 1968. 9.

There is no question about the structural effectiveness of these two buildings, or their 'firmness'. A ball is one of the most efficient structural shapes known to mankind. It has the smallest surface area to volume ratio of all forms, and it is an innately stable structure, not requiring cross bracing, like a box or rectangle. Both Buckminster Fuller's geodesic house and garage fulfil the architectural criteria of 'firmness' and structural stability.

The amenity or 'commodity' of the dome house and garage does not appear to be as successful. A vehicle is a rectangular object, which does not relate to the plan or volume of a dome. In the domed garage much of the internal space is wasted. In the domed house there are similar problems. The standard devices that clutter a home such as; beds, sinks, refrigerators and toilets are basically rectangular objects, which do not fit easily within or against the curving walls. The result of this conflict may be some very awkward junctions. The utility of both the geodesic home and garage is lacking. In this case a structural fascination appears to dominate and override other aspects of the design.

The attractiveness or 'delight' of these architectural forms may also be assessed. The assessment of architectural 'delight' is a highly complex and variable task, dependent upon many factors. In assessing the image below, the designer may ask whether a structural fascination dominates over a concern for the design's aesthetic.

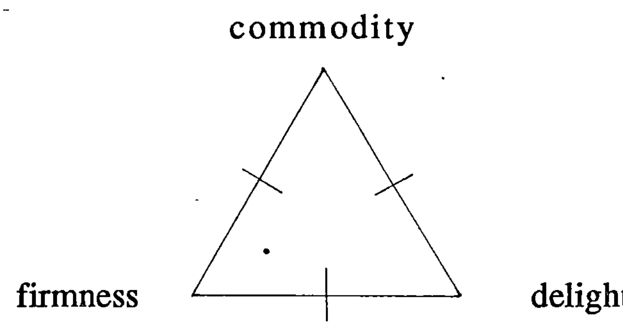


Shingled watershed plywood garage, built in Iowa 1957. Buckminster Fuller. 10.

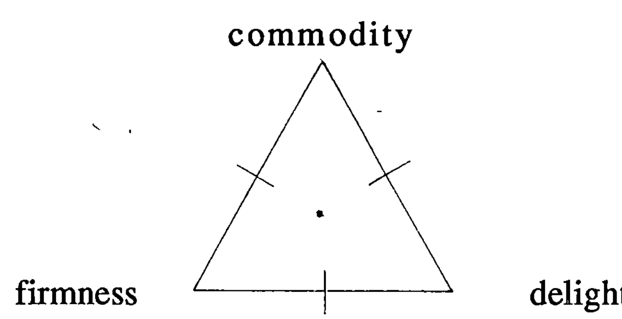
The previous analysis discusses the less successful use of dome technology, as applied to design. This does not suggest that geodesic structures do not have appropriate applications, or design roles in which they can perform successfully. One such design application is the modern bush walking tent. A structural dome is ideal in this instance as it is light and has a very high strength to weight ratio. The aerodynamic shape and flexible form can resist winds of far greater speeds than the traditional triangular tent. Some dome tents are said to resist winds of up to 40 knots. The flexible load shedding structure, constructed from fibreglass struts, is designed to spill winds that would easily collapse another tent. The necessity for a tent to contain rectangular items is less essential than it is for a house to contain rectangular commodities. Sleeping bags, packs and walkers fit comfortably into a domed space. The dome tent proves to be as practical and functional as it is strong, readily passing both the criteria of firmness and commodity, with neither aspect dominating over the other. In the assessment of 'delight' or aesthetic appeal the answer is once again a personal response. It may be suggested that a scene consisting of brightly coloured domed tents, set in contrast to a natural landscape, is a beautiful sight.

To compare these examples consider the following diagrams. In the diagram the aspects of 'firmness' 'commodity' and 'delight' form an equilateral triangle. The space enclosed within the triangle represents the boundaries of architecture, and the dot floating within it marks the character of the example. The proximity of a dot to a corner represents a leaning towards this aspect of design, and possibly an over emphasis of it, at the expense of other design aspects. An equilibrium exists at the centre of the triangle, at this point all concerns are in balance. It indicates a successful design response.

The domed house and garage

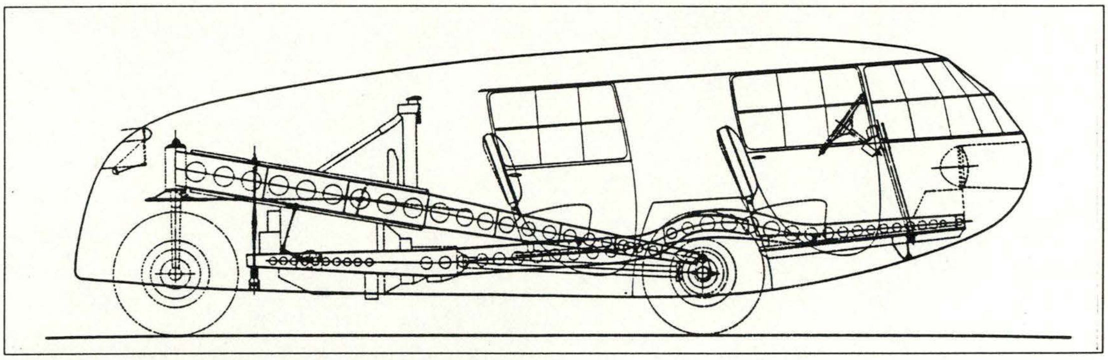


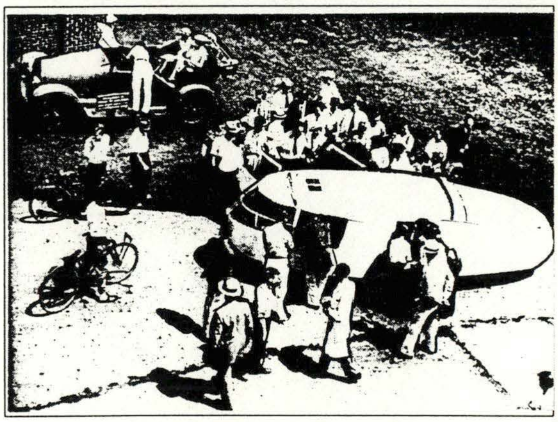
The Dome tent



Buckminster Fuller developed many of his structural theories directly from nature. He then developed these theories into technological applications. Both stages represent profound leaps in thought. In the subsequent stage of applying these ideas to architecture the technological factors were foremost. Buckminster Fuller's buildings may be viewed as technological expressions rather than functional pieces of architectural design. It may be said that Buckminster Fuller was so closely involved with the development of the technologies, that it may have been difficult for him to sacrifice aspects of the technological ideal for the benefit of the architectural concerns.

The Dymaxion car designed by Buckminster Fuller is another example that may shed some light upon the regenerative approach. Even though it is not an architectural example it does highlight a number of potential traps. The first concepts for a Dymaxion car began with Buckminster Fuller's working designs for the 4D Dymaxion house in 1927. To service these autonomous homes Buckminster Fuller designed a transport unit, that conformed to the same design principles, for maximum efficiency and utility. The first vehicle designs were for a device that flew, floated and drove. It was called the "4D twin, angulary-orientable, individually throttleable, jet-stilt, controlled-plummeting transport." or the "zoomobile". In 1933 one of Buckminster Fuller's friends offered to put up the money to develop and build a prototype. Buckminster Fuller immediately began construction.

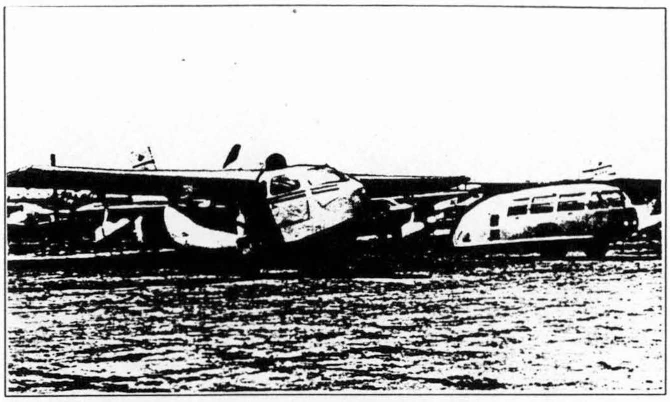




Drawing of the first built Dymaxion prototype. 11.

Picture of the Dymaxion car next to a regular 1930's car. 12.

The Dymaxion car was a revolutionary vehicle when compared to other automobiles being produced during the thirties. The leap in automotive technology embodied in the first prototype is enormous. The car exhibited numerous innovations - among them; front-wheel drive, rear engine and rear wheel steering, aluminium-bodied, chrome-molybdenum aircraft steel chassis; 1/8 th-inch aircraft shatter proof glass; and air conditioning. In addition it also introduced complete aeronautical streamlining to an industry that had not advanced far beyond the form of horse drawn carriages and buggies.



Picture Dymaxion car next to Seabee amphibian plane flown by Buckminster Fuller. 13.

The Dymaxion car was obviously not designed by an evolutionary process, and adaptive development of current car technology. The design process was a regenerative one that involved the transfer of design technologies between the disciplines. Almost all of the innovative parts of the car are derived from other fields of design. The curvaceous body of the Dymaxion car is similar to the framing of a sailing yacht. The body is created from laminated timber ribs. The material used to build the frame was ash, a timber renowned for its strength and flexibility, and frequently used in the construction of both aeroplanes and yachts. The light frame of the car was clad in an aluminium skin, similar to the surface of an aeroplane. The roof, (of the first two models) was covered in taunt canvas and attached with snap fastenings, comparable to the canvas covering on a yacht.

In the creation of the Dymaxion car Buckminster Fuller reapplied and reused many of the construction methods and tools that had been used to create the original generative design models, upon which the car was based. For example, the ash frame of the Dymaxion was steam bent according to methods of yacht construction. The mix of technologies gave the vehicle an appearance somewhere between that of a boat and an aeroplane. The image of the Dymaxion car parked next to a Seabee amphibian plane owned and piloted by Buckminster Fuller displays how closely this car is related to aeroplanes rather than automobiles.

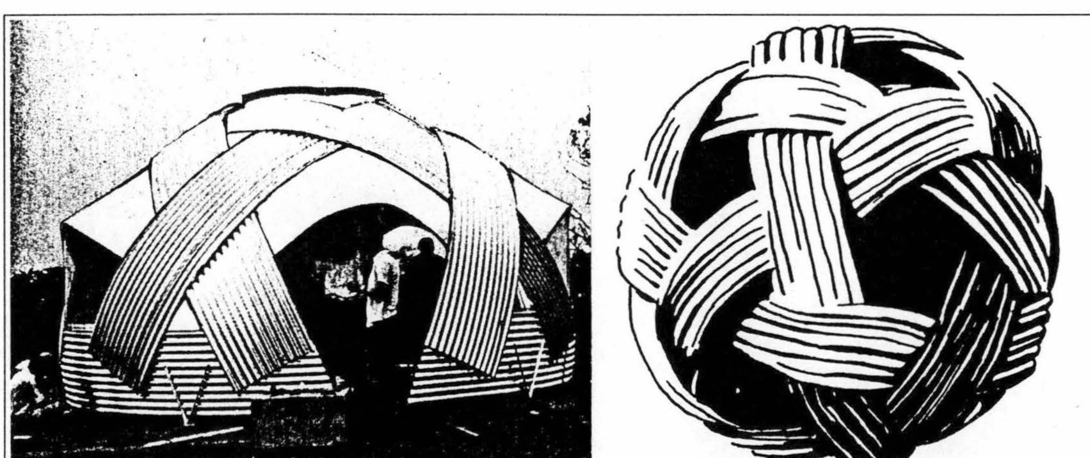
A very successful aspect of the design is the vehicle's lightness and its high strength to weight ratio. By giving the vehicle a structure and streamlining, that was at that stage only found in aeroplane and yacht design, Buckminster Fuller was able to vastly improve fuel efficiency and reach much higher road speeds. The Dymaxion car could reach 120mph with an ordinary stock V8, (90 horse power) engine. A regular 1933 sedan would have required an engine of 300 horse power to reach a similar speed.

In most respects the regenerative application of design technologies was successful. What proved to be less successful was the associated aerodynamics of the form. The Dymaxion car experienced problems with uplift. For an aeroplane uplift is appropriate, for a car it is obviously not. The combination of rudder-like steering (derived from yacht design) and a lifting tail was dangerous. The tail, designed to work as faring and prevent the rear of the car from leaving the ground, was insufficient. At higher speeds the back wheel tended to lift off the ground, and when this occurred all steering abilities were lost. Unfortunately such a combination of factors was related to the cause of a fatal accident with the second vehicle in 1934. In 1943, in response to the problems associated with rear wheel steering Buckminster Fuller designed Dymaxion No.4. The modified design had front wheel steering and a rear wheel that could be unlocked for acute turns. The ability of the Dymaxion car to turn acutely within its own length, (achieved by single rear wheel steering) was a highly favoured aspect, and possibly why Buckminster Fuller struggled to retain it in the first three prototype designs.

In conclusion, it is important to be aware that when reinterpreting a design aspect, in a regenerative manner, other properties that associate themselves with this aspect may follow. For example, the form of an object can not often be reinterpreted without the equivalent structure to support it. In the case of the Dymaxion car the shape could not be reinterpreted without the characteristics associated with the aerodynamics of its form.

Buckminster Fuller frequently began his design process, not with a problem to solve, but with a technology to apply. Buckminster Fuller discovered and developed many of his technological ideas beyond the constraints of an application. After a period of development he often sought to apply the design theory or technology, to prove its functional worth. This is most certainly the case with the geodesic buildings. This approach is different than one that begins with an architectural problem and then seeks an appropriate solution. An idea cast without the constraints of a physical application in mind may be difficult, at a later time, to apply to a real project. There are of course a number of cases in which Buckminster Fuller set about the regenerative process from the opposing tack. For example, in the construction of the Dymaxion car, the design problem was perceived first. The brief was established before Buckminster Fuller sought and gathered the appropriate design technologies, amalgamating them into an innovative automobile design.

In the design of the corrugated hut, pictured below, an approach that begins with an observation before the establishment of a design brief is evident. This discovery of a woven toy slotted neatly into Buckminster Fuller's structural interests. The toy was applied in a regenerative sense to a comparable architectural problem. The personal interests of an architect can dictate and direct what they may discover in the way of comparative design analogies. An architect may find design models in areas that they are familiar with, or have a personal interest in. In Buckminster Fuller's work a personal interest in flying and sailing may be observed.



Corrugated aluminium 18-foot geodesic dome constructed by Buckminster Fuller and students at the University of Natal, at Durban, 1958. Compared to a woven child's toy.
14.

This case study has examined only a few of Buckminster Fuller's design contributions, but it has discovered quite a number of design issues. The examples have highlighted concerns that are essential knowledge for the architect wishing to employ a regenerative approach. These matters are included in the summary of the design principles that follow.

A summary of the design principles

As identified in the previous sections and in the analysis of Buckminster Fuller's design work there are a number of basic principles that may aid in the transfer of design ideas into architecture. The following list of principles are intended to act as a guide for architects wishing to employ a regenerative approach. They further define what may constitute a successful regenerative process. The points are ordered under the headings of; sourcing ideas, developing the regenerative idea, and the practical application of the idea.

SOURCING IDEAS

∞ **Design ideas are frequently the result of the interaction of established concepts and new situations. They do not arise independant of experience or context.**

- The designer may discover a solution by simply combining past concepts in new and useful ways.

∞ **A creative response may be initiated by the challenge to seek a solution to a problem for which there are no rules or routines at hand to follow.**

- To solve such a problem the designer may seek a design model upon which to base their response.

∞ **Defining the problem is a critical task, as a problem well stated is half solved.**

- To aid in the selection of a regenerative model, a design brief needs to be clearly established. This may clarify the purpose of the design mission and make finding an appropriate model easier.
- A comprehensive analysis of the design problem may lead to a greater chance of success during the design synthesis and design resolution phase.

∞ **It is vital that the design constraints and parameters of the project are clear. These limitations establish and set the context into which an idea is transferred.**

- A design model taken from another discipline, with different aims and priorities, may misdirect the architect if they are not consciously aware of their own design goals.

∞ **The quality of the design result is strongly influenced by the scope and quality of the research.**

- Energy applied to the task of seeking ideas may increase creativity in the same way as the nurtured plant will sprout more seeds.

∞ **A more structured regenerative approach may enhance creativity.**

- An awareness of regenerative systems, may lead to the designer realising that there are already elements of a regenerative approach in their design activities. A conscious understanding of the regenerative process may therefore aid future design programmes.

∞ A designer may increase their ability to find appropriate design models by enlarging their stock of ideas and multiplying their design observations.

- Although at times the discovery of ideas may seem uncontrollable the designer may intentionally improve their ability to solve design problems by simply being more creatively alert.

∞ Memory is a prodigious source of information for regenerative ideas.

- The memory may be viewed as a depository of design information from which to draw regenerative inspiration.
- A way to seek ideas may be to consciously track through this resource, for appropriate design models that compare to the problem we may be dealing with.

∞ The premature judgment of a design idea is best avoided.

- If the intellect judges or passes up an idea too early the designer may sever its regenerative potential.
- It is necessary to approach the design mission with an open mind as all ideas are worthy of examination.
- The architect will need to be prepared to test experiment and feel, not assume.

∞ Discovering an appropriate design model may be as simple as asking the right question.

- By constructing deliberate and provocative questions the designer may consciously direct the creative mind along the path of comparative association. Asking questions such as; 'What is this like?' ... 'What does it suggest?'... 'Is there a parallel?'... 'What can be adapted?' or 'Is there something to copy?', may surface a number of comparative models reapplicable to the problem at hand.

∞ In a regenerative approach to design the architect may need to search far and wide for design inspiration.

- The architect needs to be prepared to look beyond a personal view for design ideas, as there is a great deal of potential in the exchange of ideas between the fields of human endeavour.

∞ Observation is a key activity in the regenerative process.

- The architect may need to hunt for design inspiration and keep constantly on the alert in case it comes their way.
- The architect may require to objectively fill their minds with regenerative information, as this knowledge may in the future find a design application.
- A chance encounter may provide the designer with the necessary lead for a design response. Such an event may not be fulfilled if the designer is not aware or prepared to make the observation when it stands before them.

∞ **In the search for ideas the boundaries between the academic disciplines need to be resolutely crossed.**

- The architect should be aware of obstructions that may prevent them from identifying the value of a design idea.
- A technology discovered and developed at a specialist grade may be very difficult to understand by anyone other than another specialist in the same field. Specialised terminology or 'jargon' has the potential to inhibit the exchange of design ideas and technologies.

∞ **A primary design generator may be found in almost any object or artifact made.**

- This is because every object made by humanity has required design thought to produce. No line can be drawn or no structure can be built without creative input.
- Artifacts surround us in our waking lives with their images pervading our dreams. They are more than just the physical results of our labours, essentially reflecting our imagination and strivings. The simplest and dullest of artifacts may be as much a source of inspiration as the most fantastic and unique products. By not accepting artifacts as common or dull the designer may draw from their embracing philosophies, prejudices, causes and contradictions.
- There are numerous design ideas that are thought to be of no further use in our modern day society, the reconsideration of these may supply the designer with a wealth of design inspiration.

∞ **The architect may discover that nature holds numerous ideas that are reapplicable to building design.**

- Nature is a prime and inexhaustible source of inspiration which lies at the core of conceptual understanding. Its ever presence affects the development of perception and therefore resulting actions.
- Inspiration from nature may come from the smallest details or embrace the largest of concepts.
- Our technical understanding of the environment is forever increasing and our emotive responses changing, this opens new opportunities to interpret and reapply such knowledge to architectural design.

∞ **The number of times an idea may be reapplied in a regenerative sense is unlimited.**

- Under appropriate circumstances an idea may be applied to more than just one discipline, it may be exchanged, remodelled and reapplied 'ad infinitum'.

DEVELOPING THE REGENERATIVE IDEA

∞ **A design model should only be used as springboard.**

- A design model can not simply be reapplied, unchanged, to a new design context, it will need to be shaped by it.
- Each designer is able to see further than its predecessors have, as they have provided the springboard from which to leap.

∞ Too close a focus on the design problem at hand may hinder the creative activity.

- People tend not to ask questions about problems that they are thoroughly acquainted with.
- Once a certain path to a solution is cut it may be difficult to create a new one. It may be easier to tend towards the path that is known, or a routine of thought worn by previous thinkers. Sometimes a level of ignorance can enable the designer to discover a successful path that may not have been pursued, or followed if the implications where realised in the first instance.

∞ The architect may need to broaden their design exposure and examine a design response under a range of self imposed design views.

- It may be easier to solve a design problem by assuming an objective point of view. The new perspective may be valuable, as from it the designer may see the problem in a different light.

∞ An accidental or unexpected lead may provide inspiration for the discovery of a provocative design result.

- Even a failed test may produce a successful result.

∞ Practice makes perfect.

- It is as important for the designer to exercise their creativity. The human mind is like a muscle, when we don't use it we weaken its ability to function, and it may suffer from mental atrophy.

∞ Fruitful design may not occur in isolation. Cross pollination is necessary to create a new and healthy design response.

- The tendency to separate areas of study into compartments works against the regenerative process. Categorisation limits the range of ideas that specialists are exposed to and therefore limits the ability to establish analogies and metaphors, and discover new ideas.

∞ The architect may use a generative original as a predictive model.

- It may give forecast to the design result and may provide the designer with a certain amount of pretested design knowledge.
- The architect may be selective, taking only what has proven to work .

∞ The designer may discover, that in a regenerative process, one association leads to another in a linking chain of design options and regenerative possibilities.

- The designer may develop the analogy, by comparing what is known, to what is not known. The comparisons may result in further knowledge, forming a new base from which the designer may once again move forward. The comparative process is like climbing a ladder, each step cannot be taken unless there is one below upon which to rest the other foot.

∞ **Complexity or cost may be a regenerative restraint.**

- An overly complex or expensive technology may not be applicable to architecture as constructional or costing constraints may prevent its application to building design.

PRACTICAL APPLICATION OF THE IDEA

∞ **In the application of a design idea it is essential to sort out what parts of the generative model are useful and illuminating and what elements are potentially misleading.**

- The designer may need to be selective when utilising the generative model, as it is seldom that a model is totally applicable to a new design task.

∞ **Conceptual understanding of the associative process may be further extended by its visualisation as a linking chain of comparative thoughts derived from an associative model.**

- Understanding the nature and the structure of the associations being derived may be important.

∞ **A critical decision is knowing when to make a break from the chain of design associations that emerge out of the establishment of an analogy.**

- It is of utmost concern that the associations do not override the architectural concerns and dominate the design result. The architect needs be wary of the analogy gathering to greater pace and 'snow balling' beyond the control of the designer.
- It can be an easy mistake to blindly follow the successive associations that arise out of an analogy, forgetting to reference them back to an architectural priority.

∞ **It may be best to avoid the overly literal interpretation of a selected model.**

- It is less likely that a direct copy will successfully relate to its new context, as the original model may have been designed to suit its own specific conditions.
- Appropriateness is a key issue in the interpretation of a regenerative model. It is vital that the model is appropriate to its new application, and that it sits comfortably within its new context. The application of a regenerative idea is balanced like a finely set scale. The scales may be easily tipped and the interpretation trivialised by taking the association too far.

∞ **The layering of numerous extrapolations, from various sources, may often produce a finer result than the monogamous commitment to one source.**

- Often there will be a number of appropriate models that may be applied to a design problem. A combination of the most appropriate aspects of each regenerative model may produce a more successful result than an insistence upon one model.
- Context is a variable that directly affects the success of a regenerative idea. In one context an idea may seem new and innovative in another it may be cliched.

∞ **A crucial aspect is the architects ability to fully realise the design and overcome the difficulties involved in the creation of the built object.**

- Models materials and tool technology are apart of the making process and closely affect the design outcome.
- The difference between a good idea and a creative success is in the application of the idea.
- A design may look good on paper but this does not ensure that it will work well in reality. At times a three dimensional model may be the only way to conclude whether an innovative idea will succeed or fail.
- The numerous tests that can be carried out on a three dimensional model will allow the architect to actively improve the idea, as a model is just one step away from the real building in both a structural and aesthetic sense.
- For the designer there is a capacity to stimulate the creative mind by taking two dimensional marks on paper and converting them into a three dimensional model.

∞ **When transferring an idea the architect will need to carefully consider how to apply the idea.**

- By examining how an original model was realised the designer may discover technical and constructional knowledge reapplicable to the new constructional task.
- The process may involve transferring not only the form of the idea but also the original methods, tools and techniques used to construct it.

∞ **Whatever may have the ability to limit building design will have a corresponding ability to limit the reuse of an idea as applied to architecture.**

- The designer may discover that the reapplication of an idea is limited by preconceptions, by functional or constructional constraints or by available tools and available technology.
- The regenerative process may be limited by both psychological preconceptions or physical limitations.

∞ **Many problems and design conflicts may arise if the links between the building and the regenerative source are only tentative.**

- The links need to be obvious, as the more obscure the allegiance the more likely it is to fail.
- It may be best to avoid a contrast between the original role or function of the primary generator and its role or function in design application.

∞ **The greatest potential for a design success occurs when an idea is inserted into architecture from an area of design where the knowledge discovered is at a technological pinnacle.**

- This knowledge may be the result of tradition or reflect a concentration of effort inspired by economic or political motivations.

∞ **When reinterpreting an aspect of design, it is important for the architect to be aware that other qualities that associate themselves with the design idea may follow.**

- When transferring a technology into architecture the designer may discover that additional associations may follow the re-implementation of a technological idea. For example, when transferring a structural system or a specific constructional detail into architecture the designer may discover that they also establish a visual association with the original model. The result of this association will likewise require consideration.
- For a regenerative result to be successful all subsequent design associations need to be appropriate to the new task.

∞ **When a designer reuses a design technology they may discover that they are confronted by the problem of ownership.**

- Ownership may limit the development and the improvement of an idea by another mind.
- The pressures of a commercial system and the desire for immediate returns may severely limit the regenerative development of ideas.

∞ **The designer employing a regenerative approach needs to be aware that sizes have a certain fixity.**

- Original scales have a certain fixity that is attributed to form, to purpose, to function and to the materials used. It is important to be aware of these aspects when exchanging and at times altering the scale of the regenerative idea.

∞ **In the application of a regenerative idea architectural concerns should dominate and direct the design not the priorities of the analogy.**

- A constructive models will not disrupt the buildings purpose its structural stability or the aesthetic design result.

Concluding statements

There appears to be, as concluded from the discussions, a useful concept of regenerative design applicable to architecture. The examination of regenerative design systems has the potential to improve idea generation abilities and possibly the quality of the design result. The regenerative concept involves the sourcing, modification and reapplication of ideas and technologies to new design situations. The development of ideas by regenerative means encompasses catalytic and self perpetuating systems. Elements of a regenerative process may be identified in the work of many designers. The approach forms a linking element between the design disciplines.

Regenerative patterns and processes appear to be evident where ever the designer may look. Regeneration is a basic component of our everyday lives, and an essential ingredient of our epistemology. The entire design world may be viewed as an example of a regenerative system, that is cyclically revisited. Any of its elements may await design interpretation by creative minds. The continuity between ideas has provided the stimulus for the examination of this concept and its relationship to architectural design. The value of an associative method that draws upon a wealth of experience based knowledge in solving design problems can not be overemphasised.

The production of design ideas appears to be critically dependent upon the contents of the designer's mind and upon how the ingredients are mixed in a complex process to derive a design solution. It is commonly accepted that the designer can not work in sensory isolation, or without a reservoir of knowledge or design skill gained from previous experience. The process may be compared to the complexity of a view through a kaleidoscope. The pieces combine to create an image that is dependent upon the number of stones, and upon the individual shapes and sizes. Just one new stone, that is just one new thought, can vastly increase the number of potential combinations. To pin point exactly how ideas and design thoughts are shaped, is very difficult, as every mind is filled with information and experiences, unlike that of any other.

A regenerative response essentially involves purposely re-examining design models that have direct ties to a new design programme. This analysis is used to inspire further thought and creativity. Any object or experience may be the source of inspiration and the catalyst for a design response. After the association is established, a process of adaption is necessary to effectively apply the design idea to the new design context. Successful design solutions may simply be the result of the modification of an existing design model.

The regenerative approach provides a structure for the elusive search for ideas. The numerous techniques presented may be employed to stimulate the creative mind. Design inspiration may be discovered from a conceptual, to a detailed level, through the establishment of appropriate and provocative associations with the design generator. By following a regenerative approach to design the architect may move forward in creative pursuits with greater certainty, and possibly a higher chance of success.

Regenerative design techniques allow the designer to side step impeding creative blocks. Asking simple design questions, or applying any of the creative techniques and methods examined may allow the designer to side step creative hurdles, and discover design models that inspire creative thinking.

The components of the regenerative approach may be employed as design tools. The critical constituents being, metaphor, simile and analogy. These elements establish the initial links with the existing design generator, encompassing the potential to inspire new design ideas. With further testing, design manipulation and innovation, appropriate results may be discovered.

Facing a problem from a different perspective enriches the design outcome. Numerous design thoughts and options may be discovered from such a position. The approach encourages delaying design judgment, as all ideas have the potential, if seen in the right light, to stimulate creative thought. The active stockpiling of ideas is important in supplying and triggering associative chains of thought. If the designer increases their creative input they may increase their creative output.

As illuminated in section B, there is an extensive range of ideas that are applicable to architectural design. The 'primary generator', that is the essential hint that comes from the existing model, may be derived from an artifact or a natural object, or possibly from a less easily defined experience. In the selection of the design model both emotive and rational thought processes are involved. The range of design models that have been discussed eluded to how widespread and diverse design inspiration may be.

Many difficulties face the architect when drawing inspiration from diverse areas of knowledge, understanding and being able to direct an associative process is essential. Design procedures may operate differently in different situations and for different people, but some direction is suggested in the design principles. The critical issues affecting the application of a regenerative approach, are discussed in the summary of design principles. These principles aid in the application and control of the regenerative design process.

The regenerative concept has been developed and presented as a process of some relevance to architectural design. This idea finding activity may increase design confidence, and has the potential to enhance the designers ability to discover and successfully apply ideas to architecture.

Notes

The place and date of publication are given only when the reference does not appear in the selected bibliography.

Information is collated in the following way;

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Section A:
Introducing the design approach

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Natural inspiration

Natural Inspiration

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Finding the 'primary generator'

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3. Image - drawing, Leonardo da Vinci - Wallace, R. The World of Leonardo 1452 -1519, p.116

Protective devices

1. Image - Patents : Internal screw stopper 4,184/1879, Barrett, Henry. External screw top with liner 12,629/1889, Rylands, Dan. Crown Top 2,031/1892, Painter, William. - Schmookler, J. Patents, invention, and economic change:data and selected essaysp.99
2. Image - Zip fastener, Patent no. 12,261/1915. Sunback, Gideon - Schmookler, J. Patents, invention, and economic change:data and selected essays, p.143

Practical application of the regenerative idea

The application of the regenerative idea

1. Image - Renzo Piano, Cultural centre, Noumea, New Cal. 1991, and comparative shell structure - Buchanan, P. Renzo Piano: Building Workshop, p.10
2. Quotation - Rowe, P. Design Thinking, p.81
3. 1. Frank Lloyd Wright, Falling water, 1936-37.
   2. Le Corbusier, Villa Savoy, 1929-31.
   3. Eric Mendelson, Einstein Tower.
   4. Joen Utzon, Sydney Opera House, 1957-73.
   5. Window detail of the Islamic Embassy, Paris.
   6. Gaudi, Parc Geull.
   7. Frank Gerhy, Fish restaurant, Kobe.
   8. Kazumasu Yamashita, Face House, Kyoto, Japan 1974.

The creation of the regenerative architectural object

1. Quotation - Steadman, P. The evolution of Designs, p.61
2. Quotation - R. B. Fuller - Buckminster Fuller, R. Ideas and Integrities
3. Image - Buckminster Fuller - Buckminster Fuller, R. The Dymaxion world of Buckminster Fuller, p.1 plate.1
3. Quotation - Lambert, S. Drawing Technique and Purpose, p.40

Hands-on material contact in the development of regenerative ideas

1. Quotation - Black, M. Education as a Discipline, p.290-91
2. Citation - Coley, C. Jean Prouve.
3. Image - Chair designed by Prouve - Jean, P. Jean Prouve : Mobel, p.87
4. Quotation - Prouve - Jean, P. Jean Prouve : Mobel, p.103
5. Image - Sitmun's Throne - Bramwell, M. The International Book of Wood, p.98

Tool technology

1. Image - Besson's ornamental turning lathe 1578 - misplaced.
2. Quotation - Scruton, R. The Aesthetics of Architecture, p.12

Fixity of Scale

1. Image - Renzo Piano, IBM travelling pavillion - Buchanan, P. Renzo Piano : Building Workshop, p.116
2. Image - Dymaxion Deployment unit - Hatch, A. Buckminster Fuller: at home in the Universe, p.160
3. Image - Kaiser Dome Honolulu - Hatch, A. Buckminster Fuller: at home in the Universe, p.207

Section D:
Guiding Principles

Robert Buckminster Fuller

1. Image - Ninety strut tensegrity enenticontahedron (90-sided figure) Princeton University, 1953. - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.168, plate.273
2. Quotation - Kenner, H. Bucky : A Guided tour of Buckminster Fuller, p.100
3. Image - Tensegrity tricontahedron (30-sided figure) - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.211, plate.272
4. Image - The Capitol, Washington, initial building 1792-1827, dome 1855-56. - Rawson, P. Design, p.27
5. Image - Floatable cloud structure, - Hatch, A. Buckminster Fuller: at home in the Universe, p.237
6. Image - Dymaxion House project, 1927. - Buckminster Fuller, R. Ideas and Integrities, p.194
7. Citation - Sir Henry Wotton 1624.
   "Well-building hath three conditions; Commodity, Firmness and Delight".
8. Image - Geodesic plydome, farm shelter 1957. - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.217, plate.442
9. Image - Geodesic domes, Libre, Colarado, 1968. - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.116, plate.336
10. Image - Shingled watershed plywood garage, built in Iowa 1957. Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.218, plate.445
11. Image - Drawing of the first built Diaxion protoype - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.107, plate.111
12. Image - Dymaxion car next to a regular 1930s car - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.110, plate.130
13. Image - Dymaxion car next to Seabee amphibian plane flown by Fuller - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.113, plate.144
14. Image - Corrugated aluminum 18-foot geodesic dome constructed by Fuller and students at the University of Natal, at Durban, 1958. - Buckminster Fuller, R. The Dymaxion World of Buckminster Fuller, p.223, plate.463
15. Image - woven childs toy - Kenner, H. Bucky : A Guided tour of Buckminster Fuller, p.44

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